Table 4-6. Change in Labor Years, GDP, and Disposable Personal Income: 2010–2050

Category	Employment		U.S. GDP		Disposable Income	
1. Farm	216	0.0024%	$21B	0.0017%	$11B	0.0012%
2. Farm-Demanding Ind.	-5,286	-0.0594%	-$719B	-0.0598%	-$887B	-0.0976%
3. Thermoelectric	-91	-0.0010%	$2B	0.0002%	-$155B	-0.0170%
4. Hydroelectric	622	0.0070%	$120B	0.0100%	$47B	0.0052%
5. Industry and Mining	-8,428	-0.0946%	-$1,324B	-0.1101%	-$746B	-0.0820%
-Not including shutdowns	-1,641	-0.0184%	-$285B	-0.0237%	-$197B	-0.0217%

The thermoelectric input variables produce economic consequences of greater magnitude than the farm input variables and of slightly smaller magnitude than the hydroelectric variables. The thermoelectric input variables contain information on retrofit activity to compensate for reduced water availability. Positive spikes in the GDP and employment occasionally appear in Figures 4-12 and 4-13, presented previously, especially earlier in time when investments in retrofit technologies first begin. However, these increases are often more than compensated for by the negative effects of increasing electricity generation costs in later years. The increases in electricity costs affect the production costs of other industries, causing an increase in the price index (inflation) throughout time, resulting in a steadily decreasing trend of real disposable personal income and reaching an annual loss of over $8 billion by 2050. Despite the net decrease of real disposable personal income of $155 billion during this period, there is a slight net increase in the GDP of $2 billion. However, that difference is due to investments in cooling retrofits that mitigate water shortages. If those retrofits were unnecessary, additional economic resources would be available for more productive use.

The only economic impacts that are positive overall are due to reductions in hydroelectric power production. Reductions in hydroelectric power increase the demand for alternate sources of power from the utilities sector (as described further in Appendix B). This increased demand causes increases in economic activity in electric utilities as power plants are built, workers are hired to work in those plants, and fuel is purchased to power the plants, while the hydroelectric plants continue to operate with essentially the same labor and costs but with reduced output. The increases in economic activity highlight a problem—most familiar to economists who analyze disasters—with using aggregate measures of economic flows for consequence analysis: the lost service of hydroelectric power production is not measured in these economic flows, but the increased economic activity necessary to compensate for these losses is measured. If hydroelectric power production did not decrease, the economic resources utilized to create power from alternate sources could be used for other means (such as building luxury items) that would improve the demand for other goods and services.

The input variables for the farm industry have the second highest change in employment and GDP, and the greatest impact on real disposable personal income. The annual loss in the GDP due to the sector hovers around $30 billion in the later years of

NMED - NORTON
REBUTTAL EXHIBIT 6 - PART 2

the simulation, while the annual loss in real disposable personal income reaches $40 billion.

The mining and industry impact shows a much greater change than the other categories of impacts, with the exception that the magnitude of the losses to real disposable personal income are slightly less than they are for the farm industry. The maximum loss in the annual GDP is about $103 billion, whereas the maximum annual loss in any of the other three categories is about $35 billion (for the farm industry). Partial and total shutdowns of mining and industry have a substantial negative effect on the economic output and are largely responsible for the substantial volatility of the economic output—when no shutdowns are included in the REMI simulation, all of the economic output variables (see Figure 4-14) decrease relatively smoothly. Because of the water allocation scheme, water availability to high-value industry never falls enough to cause industry shutdowns, thus shutdowns only affect mining through 2050. From the perspective of an individual mining operation, the sale of water rights may represent a profitable option.

Reductions in water availability to mining cause relatively severe economic consequences because mining typically uses water efficiently. As discussed in Appendix B, there are few opportunities for conservation without shutting down mining activity in states that are not adjacent to the ocean. All of the industries use a much greater share of their water for cooling, so they can conserve much greater portions of their consumption. Additionally, all of the industries simulated in the REMI model are represented as an aggregate, so no industry begins shutting down production until all industries have made all possible cooling retrofits, thus raising the fraction of water that can be conserved through cooling retrofits.[13] Because large municipal water suppliers serve most of industry, this aggregate view of a shutdown threshold is probably realistic. Figure 4-14 shows that under extreme drought at the 1% exceedance probability, water demand from municipal and high-value-added industries (with consequent demands for electric power) reduces agriculture and mining water availability to a large extent (by a factor of 2 to 1 for the water allocation logic used in this analysis). The difference between the mining curve with and without shutdowns indicates the extent to which the unavailability of water to sustain operations affects the magnitude of total economic loss.

[13] The smallest value of $\overline{\%c_t}^{\,i}$, which is the percentage of industrial consumption that can be conserved by retrofitting cooling in states not adjacent to an ocean (see Appendix B, Section B.5), is 32.4%. The median is 41.0%. For mining, on the other hand, the value of the term is always 6%.

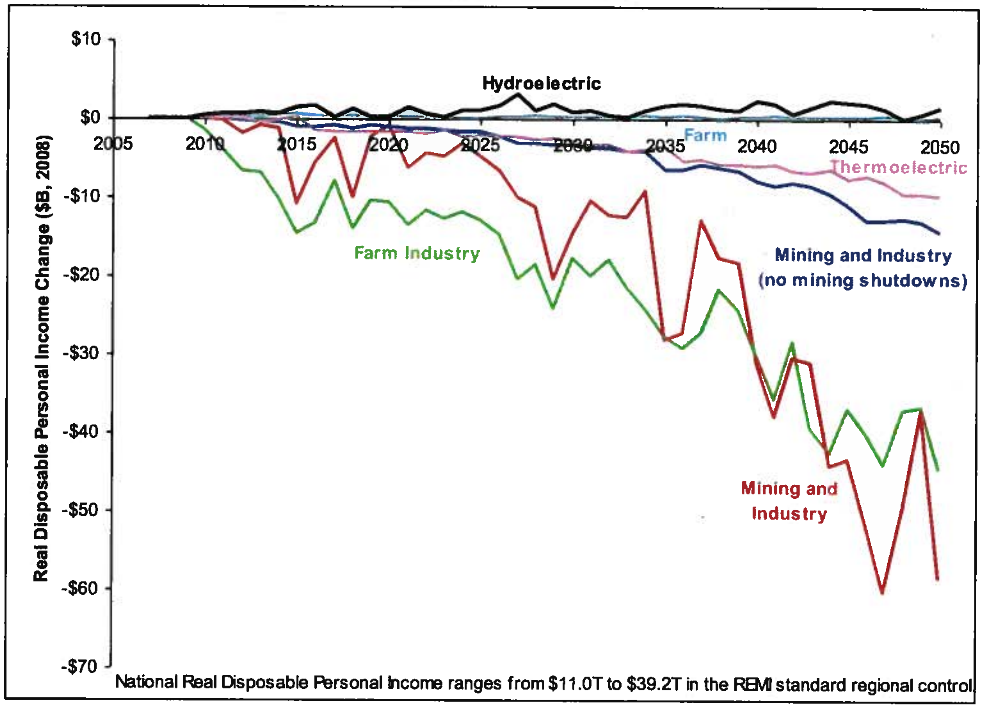

Figure 4-14. Change in national real disposable personal income (2008 USD), using farm, farm industry, thermoelectric, hydroelectric, and mining and industry inputs.

Table 4-7 lists the states with the largest percentages of gains and losses in 2050 in population and real disposable personal income (both variables were chosen because they change with a clear trend and are measures of socioeconomic dislocation). The relative magnitudes of the largest state-level changes in the different simulations are similar to the magnitudes of the national-level value.

Table 4-7. States with Largest Percentage Changes in Population and Income: 2050

Category	Population		Disposable Income	
Largest Loss (Smallest Gain)				
1. Farm	0.00%	WY	0.00%	WY
2. Farm-Demanding Industries	-0.24%	GA	-0.38%	GA
3. Thermoelectric	-0.10%	WV	-0.15%	WV
4. Hydroelectric	-0.01%	MD	0.00%	IL
5. Industry and Mining	-3.41%	WV	-4.11%	WV
-Not including mining shutdowns	-0.05%	IA	-0.09%	IA
Largest Gain (Smallest Loss)				
1. Farm	0.02%	NE	0.02%	NE
2. Farm-Demanding Industries	0.26%	OR	0.16%	OR
3. Thermoelectric	0.02%	DE	0.00%	DE
4. Hydroelectric	0.02%	AZ	0.03%	AZ
5. Industry and Mining	0.13%	OR	0.01%	OR
-Not including mining shutdowns	0.02%	OR	-0.01%	

The largest economic losses are to West Virginia in the simulation that includes shutdowns of the mining industry. In this simulation, West Virginia loses 3.41% of its projected population and 4.11% of its projected real disposable personal income by 2050. This result is expected because a large fraction (8% of output[14]) of the West Virginia economy is mining; and according to the defined water allocation scheme, mining experiences twice the proportional reduction in water availability than the higher-value-added industries.

For many of the categories of variables, the largest gains and losses for population and real disposable personal income are in states with large populations. For example, for the industry and mining category, California gains more than 58,200 residents by 2050, which is over twice as large as the second greatest increase (Florida, with a gain of about 27,500 residents). Based on the percentage gain compared with the baseline, however, California has the eighth largest gain (an increase of 0.10%). These gains in population occur despite large losses in the GDP ($3.9 billion) and real disposable personal income ($1.2 billion). Some states fare relatively worse compared with other states, and their residents choose to relocate. California, as the most populous state in the nation, is a likely destination of those emigrants. It also maintains a comparative economic advantage relative to other states in dealing with the impacts of climate change in the long term despite significant negative impacts in the short term. The concept of comparative advantage affects many of the state-level results of this study and has a long history in the field of economics (Ricardo 1817).

[14] In REMI's standard regional-control simulation, West Virginia's total output in 2050 is $203 billion, and its total output in mining is $16 billion.

4.3 The Impact of Interannum Volatility

We now present an additional analysis that was conducted using inputs to the electricity production sector to explore how the volatility of the data (i.e., the motif as discussed in the introduction to Section 2 and in Section 3.1.2) affects the average estimated macroeconomic impacts. The results from the 1% exceedance-probability simulation using the year-to-year water-availability forecasts are compared with a simulation created by linearly changing water availability to electricity production between 100% and the minimum of the 2010 to 2050 values for each state. The water-availability forecast uses the same 1% exceedance-probability data used in the previous section—the most extreme reduction in precipitation, with a 1% chance of its severity being exceeded. Many climate-impact studies assume a gradual change in climatic conditions or base their analysis on a snapshot of expected conditions in future years. These approaches neglect the volatility we explicitly address in this analysis. Volatility results show dramatic changes over time and provide policy makers a better roadmap for responding sooner to potential events than is available from linear, or smoothed, results.

Figure 4-15 shows the difference in national employment between the simulations and the macroeconomic referent using the Sandia hydrological model's simulated (volatile) water availability and using an, on average, equivalent downward linear trend over time. The thermoelectric designation in the figure just means that the water availability used is that for the thermoelectric, municipal, and industrial sectors. The forecasts of water availability show a high degree of variability. Employment varies with increases of more than 35,000 jobs in 2015, while decreases nearly reach a loss of 16,000 jobs in later years. When the simulation is conducted using a downward linear trend, increases in employment initially spike above 9,000 in 2010 but then return to a roughly steady decrease of around 1,000 jobs per year.

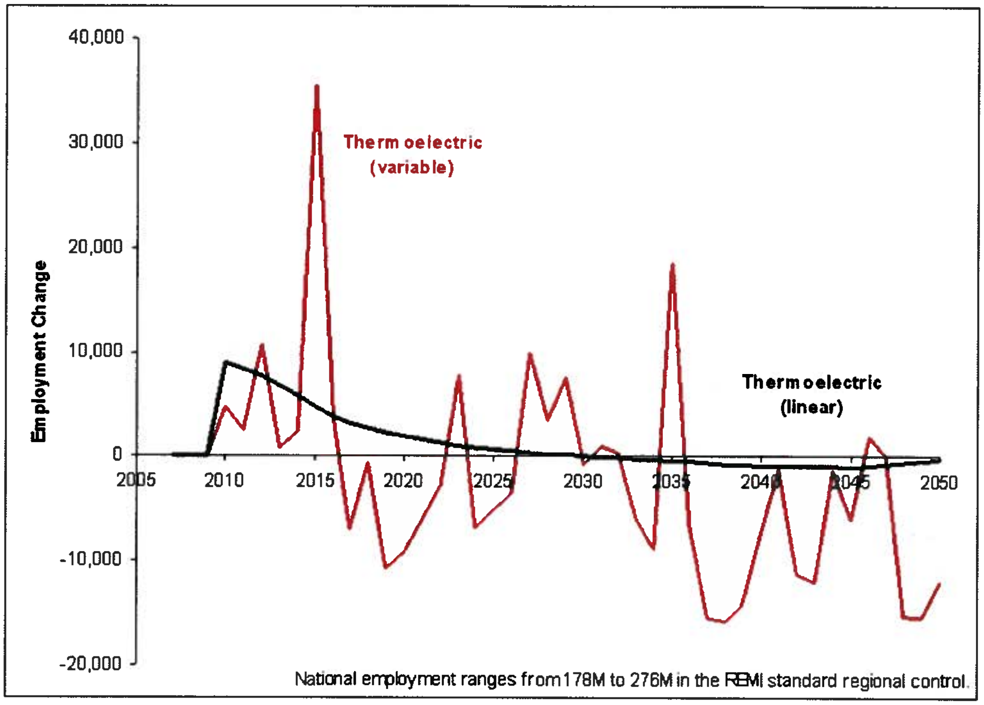

Figure 4-15. Change in national employment, using simulated thermoelectric sector water-availability data: 2010–2050.

Figure 4-16 shows the annual change in the GDP for the same simulations. The pattern is similar to the change in employment, except the magnitude of the GDP changes becomes slightly larger in the second half of the simulation for both the variable data and the linear data.

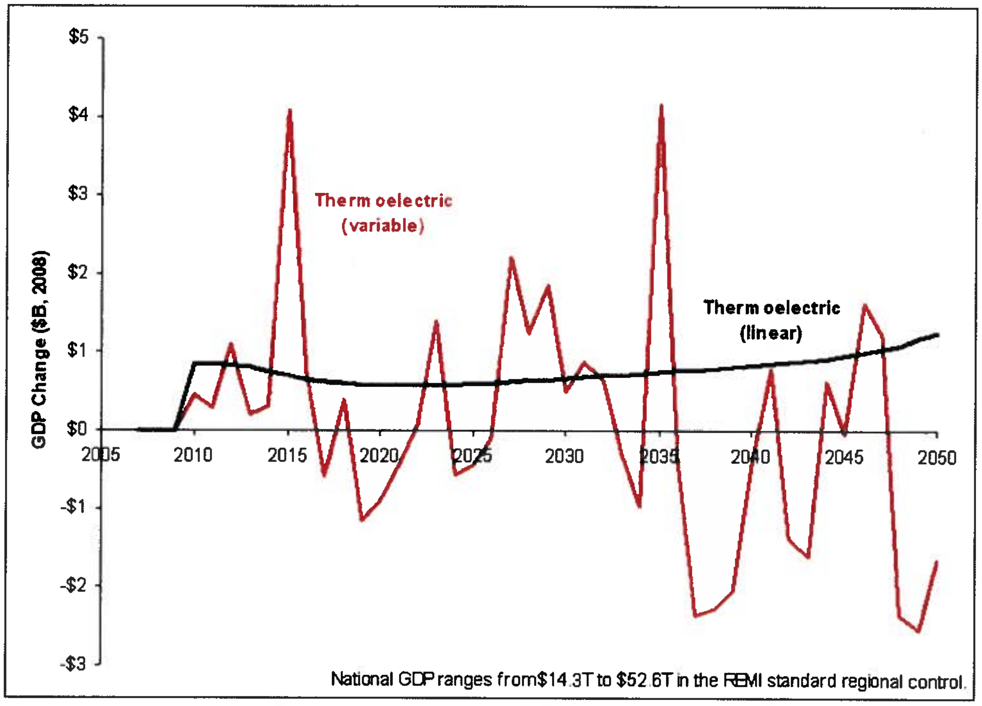

Figure 4-16. Change in national GDP (2008 USD), using simulated thermoelectric sector water-availability data: 2010–2050/

Figure 4-17 shows changes in real disposable personal income for the same simulations. Although the simulation using the forecasted water availability continues to exhibit greater volatility than the simulation using the linear trend, it is less variable than the time series of employment or the GDP in Figures 4-15 and 4-16 generated from the water-availability forecasts.

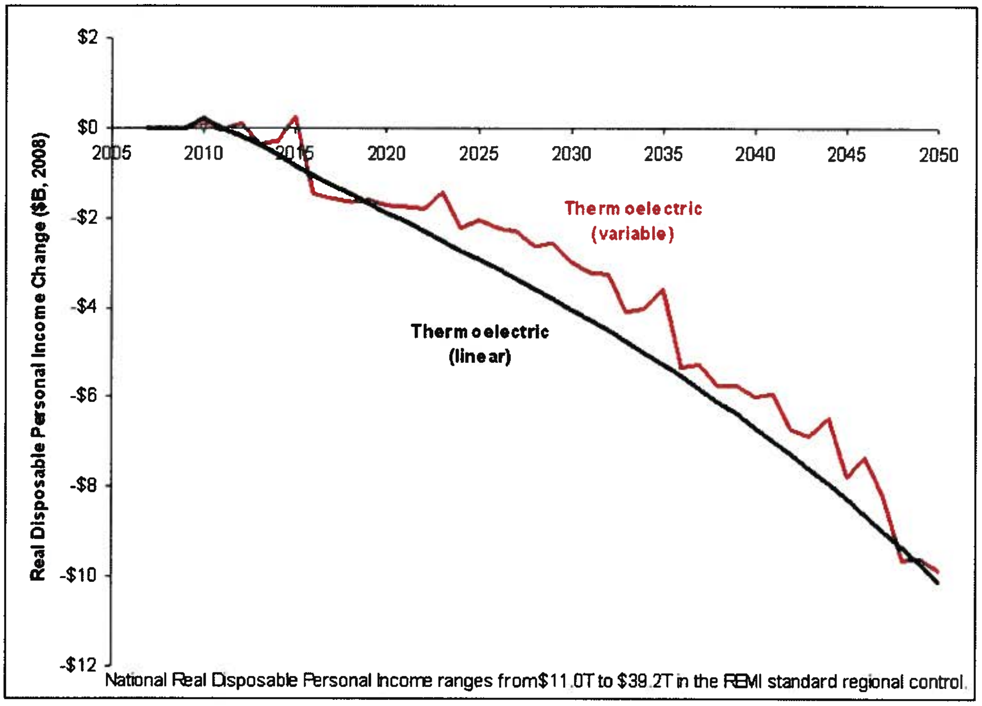

Figure 4-17. Change in national real disposable personal income (2008 USD), using simulated thermoelectric sector water-availability data: 2010–2050.

Real disposable personal income is driven by changes in commodity prices, which are affected by increases in production costs. These changes in the price level accumulate gradually over time, leading to a steady decrease in real disposable personal income as seen above in Figure 4-17. The volatility of the water availability means that the GDP fluctuates from year to year, resulting in slight fluctuations of the variable forecast from the linear forecast. Furthermore, the variable forecast has slightly higher losses than the linear forecast because the GDP in the variable forecast remains higher (smaller losses) than it is in the linear forecast in the earlier years of the simulation.

In summary, the results of these simulations suggest that the economic consequences of variable global climate change may cause more substantial year-to-year disruptions than climate change would cause if it followed a smooth linear trend. Hallegate et al. (2007) explore this issue more thoroughly. Additionally, the economic methodology (which assumes that firms make permanent retrofits to mitigate reductions in water availability) and the logic of the REMI model cause the simulations that include volatility to have permanently lower levels of real disposable personal income.

4.4 State Impacts

The national-level results show that economic impacts for the entire nation are negative. However, this aggregate look at the economic impacts of drought induced by climate change may ignore important regional differences that create disproportional positive and negative impacts across regions. Examining regional differences is particularly pertinent for this analysis because drought caused by climate change will vary in severity across the United States and different regions of the country contain different mixes of industry that will suffer to different extents from drought. For example, heavy consumers of water tend to cluster together near sources of water, thus there is little water-intensive industry in most western, arid states.

Table 4-8 shows the estimated national- and state-level risk to the GDP, employment, and interstate population migration. The values are the sum of the probability-weighted impacts over the exceedance probabilities and over the 2010 to 2050 period. The migration across states is often based on comparative advantage. Even if a given state economy is having difficulties, it may be having less difficulty than other states. If we look at the state of New York, we see that the summary impact of climate change from 2010 to 2050 is a loss of $122 billion with a 0% discount rate. This loss is reduced to $81 billion with a 1.5% discount rate and to $54 billion with a 3% discount rate. The drop is dramatic because much of the impact occurs in the later years. Note that the reduced economic activity does reduce employment by 560,000 labor years by 2050 even though the population has risen by 7,200 people due to in-migration from the even-more-affected surrounding states. This means that the unemployment in New York is increasing even more than the drop in economic activity would indicate.

Figure 4-18 through Figure 4-24 show maps of U.S. state-level impacts for the GDP, employment, population, and corn for the total risk and also for the 1% exceedance-probability (worst-case) conditions. The coloring scheme (green is good, yellow is neutral, and red is bad) used in these maps is based on the percentage impact relative to the state's size. The impact values providing the numerical population change are quantified in absolute units of measure. As an example, in Figure 4-23, which presents population changes for 2050 at a 1% exceedance probability, New Mexico is one of four states that lose more than a half-percent of their population and hence is colored red. For a state with a low population, a loss of 14,000 people is significant. Texas, on the other hand, loses around 11,600 people but is colored yellow because the percentage impact is small for a state with such a large population.

These maps show that all states suffer negative economic impacts for all variables, except for three states in the Northwest (Washington, Oregon, Idaho)—with Montana, California, and Colorado showing benefits for the summary risk but losses at the 1% exceedance probability. Washington, Oregon, and Idaho have only slightly positive impacts, but their slight gains are at the expense of other states because these three states experience the largest increases in population (Figure 4-20). Population migration in effect transfers economic activity from other states. The gains in these Northwest states are also due to the increases in demand for utilities that result from reduced hydroelectric power production. California, while predicted to suffer from the reduced precipitation in early years, is predicted to benefit economically from the later-year population movements. Colorado is predicted to prosper in the early years while there is still adequate water but experiences mounting losses in the later years as a result of reduced water. Montana is predicted to be the only state that (slightly) benefits from both adequate water and population migration. Predicted economic impacts are particularly severe in interior states where it is not economically viable to substitute to desalinated water and greatest in states like West Virginia with large concentrations of mining. For example, the GDP risk for West Virginia is estimated to be about 2.6% less than predicted without the consequences of reduced precipitation. That the U.S. Northeast and Southeast are susceptible to climate-induced water availability issues to the extent examined herein has been studied previously (Oxfam 2009; Mack, 2009).

Table 4-9 shows the state-level impacts at the 1% exceedance probability for comparison with the summary risk in Table 4-8. If we again look at New York, as we did for Table 4.8, we see that for the 1% exceedance-probability simulation, New York's summary risk is $157 billion. There is only a modest 30% increase in the 1% exceedance-probability value compared to the summary value. Note that for states like Colorado, the GDP impact reverses sign between the 1% exceedance-probability case ($34 billion loss) to the summary risk value ($1 billion benefit). In the 1% exceedance-probability simulation, New York loses nearly another 100,000 labor years compared to the summary risk value. The increase in population, however, is more than three times larger, going from 7,200 people for the summary risk value to 23,000 in the 1% exceedance-probability simulation.

Figure 4-20 shows a map of state-level population changes in 2050. Like the economic impacts, population impacts create a similar number of disproportional positive and negative impacts across the U.S. states. National population changes (changes in birth rates and death rates) due to climate are not part of this analysis, so regional population changes above those captured in the macroeconomic referent are entirely the result of Americans moving from one state to another for economic reasons. There is a strong regional pattern with states in the Southeast and Southwest losing population and states on the West Coast, the western Midwest, and the Northeast gaining. Once again, interior states with the greatest concentrations of mining, such as West Virginia and Wyoming, are most affected.

States that gain population may experience negative, nonmonetary impacts that are not modeled within this study. For example, all states adjacent to the Atlantic Coast in the Northeast are predicted to gain in population, but these states then become more susceptible to damage from presumed extreme weather associated with global climate change because of the increased population concentrations (Changnon 2003).

Figure 4-21 through Figure 4-24 show the 1% exceedance-probability impacts. These impacts are larger than the total risk reported in Figure 4-18 through Figure 4-20 but are comparable in most cases. For a few states, the analysis results are dramatically different because higher exceedance-probability (> 35%) impacts may actually show positive effects compared with the macroeconomic referent, such as in Colorado where analysis results indicate there would still be adequate water with a growing demand for goods from states that are negatively affected.

Figure 4-24 shows the predicted change in the value of corn and soy production across states at the 1% exceedance-probability. A strong regional pattern emerges with the largest percentage losses across all Southern, Southwest, and Eastern states. The Midwest, which produces the most corn and soy, experiences only minor losses while the

Northwest experiences gains. States with little or no crop impact do not have recorded corn and soy production. The 1% exceedance-probability impacts can differ in sign from the summary risk because the impacts can have different signs at different exceedance probabilities, especially in the central latitude states where precipitation goes from sufficient to insufficient as the exceedance probability decreases. Further, the comparative economic advantage among the states can shift when states negatively affected at high exceedance-probabilities relatively improve in the lower exceedance-probabilities as the neighboring states experience negative impacts.

Despite suffering greater drought conditions on average relative to the rest of the nation, California in this study shows improvements because its economic impacts are relatively less than those of other states. This comparative advantage occurs because some states have little flexibility in dealing with water shortages, for example, because there is little agricultural irrigation from which water can be diverted. In general, those states that already suffer water constraints (often due to irrigation loads combined with urban growth in arid regions) have processes in place to adjust to changes in water availability. Irrigation-water use may buffer fluctuating water shortages, assuming the viability of food imports. The value added to the national economy from certain types of industry is large compared to that for food production. Thus, the impact of reduced agriculture is partially compensated by the continued operation of high-value-added industry.

The estimated California case is particularly illuminating because these predictions are counterintuitive. In the early years of climate change the state suffers significantly from reduced precipitation and in the later years achieves comparative advantage. A review of California's current problems and future opportunities indicates support for the analysis results (Grunwald 2009). There are time-dependent dynamics among several states where the geographical movement of the precipitation conditions and the change in comparative advantage cause a reversal of cost and benefit from climate change over the 40 years. Similarly, high-exceedance-probability conditions may show benefits or losses that may be reversed with lower-exceedance-probability conditions.

Conversely, the Pacific Northwest states show improvement under climate change due to expected increased precipitation. This study is limited to the annual temporal resolution of precipitation levels (other than capturing monthly variation for agricultural assessments) and thus does not capture the impact from lost seasonal snowpack water-storage in the Pacific Northwest, which is an intra-annual process. Consequently, the estimated positive economic impacts could be an artifact of our assumptions in this study. On the other hand, people migrating to the Pacific Northwest from other states may provide positive economic impacts even if hydropower declines and there are added requirements for increasing local water storage.

As larger populations use a larger fraction of the existing water supplies, the Northeast and the Southeast experience negative impacts, even if the reductions in long-term precipitation are minimal. In general, a decreasing exceedance probability (from 50% to 1%) implies that reduced precipitation (i.e., drought) is moving north and east at a continental level, causing more-severe reductions in precipitation in areas that experience reduced precipitation at the larger exceedance probabilities (> 50%). Picture a horizontal line that begins across New Mexico and Texas and starts to sweep in a diagonal fashion as it moves north and east in the direction of Maine. Thus, areas such as Colorado go from having adequate water and benefits in high-exceedance-probability simulations to experiencing losses from reduced water availability in the low-exceedance-probability simulations. Other than in the Pacific Northwest, water availability decreases over time with climate change. The decrease in water availability may not be solely due to a change in the water supply as a consequence of reduced precipitation but due to a change in demand as a consequence of industry and population migrating into the state.

Table 4-8. National and State-Level Risk 2010–2050

Summary of Climate Impacts (2010-2050)

Region	Change in GDP (Billions of 2008$)			Change in Empl. (Thous. Labor-Years)	Change in Pop. (Thous. People)
	Discount Rates				
	0.0%	1.5%	3.0%		
United States	**-$1,204.8**	**-$790.3**	**-$534.5**	**-6,862.7**	**0.0**
Alabama	-$29.2	-$18.9	-$12.6	-246.1	-10.8
Arizona	-$69.0	-$45.8	-$31.2	-481.2	-14.8
Arkansas	-$11.9	-$7.6	-$5.0	-96.8	-2.4
California	$25.1	$16.6	$11.5	152.0	115.7
Colorado	$1.2	$0.4	$0.0	22.8	15.3
Connecticut	-$9.5	-$6.3	-$4.3	-36.4	4.7
Delaware	-$4.8	-$3.1	-$2.1	-30.3	0.0
D.C.	-$4.7	-$3.1	-$2.1	-15.5	0.5
Florida	-$146.3	-$97.5	-$66.9	-1,242.4	-55.5
Georgia	-$102.9	-$67.7	-$45.9	-752.6	-40.0
Idaho	$4.0	$2.5	$1.6	33.3	6.9
Illinois	-$10.1	-$5.1	-$2.5	-36.7	15.7
Indiana	-$21.8	-$12.9	-$7.8	-130.1	-4.0
Iowa	-$2.8	-$1.4	-$0.6	-10.3	3.1
Kansas	-$6.3	-$4.1	-$2.7	-43.5	2.3
Kentucky	-$40.6	-$24.9	-$15.6	-289.6	-21.6
Louisiana	-$14.3	-$9.4	-$6.3	-119.4	-0.9
Maine	-$0.3	-$0.2	-$0.2	-4.4	2.5
Maryland	-$23.7	-$15.6	-$10.5	-163.0	0.1
Massachusetts	-$9.0	-$5.9	-$4.1	-37.8	12.9
Michigan	-$18.3	-$11.2	-$7.1	-107.7	7.1
Minnesota	-$8.3	-$4.9	-$2.9	-36.8	7.6
Mississippi	-$7.3	-$4.7	-$3.1	-63.0	-0.8
Missouri	-$3.8	-$2.2	-$1.3	-22.7	8.3

Region	Change in GDP (Billions of 2008$)			Change in Empl. (Thous. Labor-Years)	Change in Pop. (Thous. People)
	Discount Rates				
	0.0%	1.5%	3.0%		
Montana	$0.9	$0.6	$0.4	12.8	2.9
Nebraska	-$1.4	-$0.8	-$0.4	-4.4	2.5
Nevada	-$38.7	-$26.2	-$18.1	-220.6	-2.8
New Hampshire	-$1.8	-$1.2	-$0.8	-12.1	2.6
New Jersey	-$38.9	-$25.8	-$17.6	-205.9	3.6
New Mexico	-$26.1	-$17.9	-$12.7	-217.6	-8.3
New York	-$122.9	-$80.5	-$54.4	-560.4	7.2
North Carolina	-$63.4	-$41.6	-$28.1	-492.4	-19.8
North Dakota	-$0.9	-$0.5	-$0.3	-5.4	0.8
Ohio	-$26.7	-$16.1	-$10.0	-167.7	1.7
Oklahoma	-$38.0	-$25.2	-$17.2	-312.0	-15.3
Oregon	$19.4	$12.5	$8.3	152.7	20.5
Pennsylvania	-$64.6	-$42.4	-$28.7	-459.1	-7.7
Rhode Island	-$0.7	-$0.5	-$0.3	-3.2	1.8
South Carolina	-$24.2	-$15.9	-$10.7	-235.4	-10.2
South Dakota	-$0.5	-$0.3	-$0.2	-2.1	1.3
Tennessee	-$58.5	-$37.3	-$24.4	-440.0	-23.0
Texas	-$137.8	-$91.0	-$61.9	-1,045.9	-28.5
Utah	-$10.5	-$6.9	-$4.6	-72.2	2.2
Vermont	-$0.7	-$0.4	-$0.3	-5.5	1.0
Virginia	-$45.4	-$29.7	-$20.1	-314.2	-5.9
Washington	$26.6	$17.0	$11.2	190.7	29.5
West Virginia	-$45.9	-$27.7	-$17.0	-306.4	-34.5
Wisconsin	-$6.2	-$3.7	-$2.2	-38.8	6.6
Wyoming	-$3.0	-$1.9	-$1.3	-19.2	-0.5

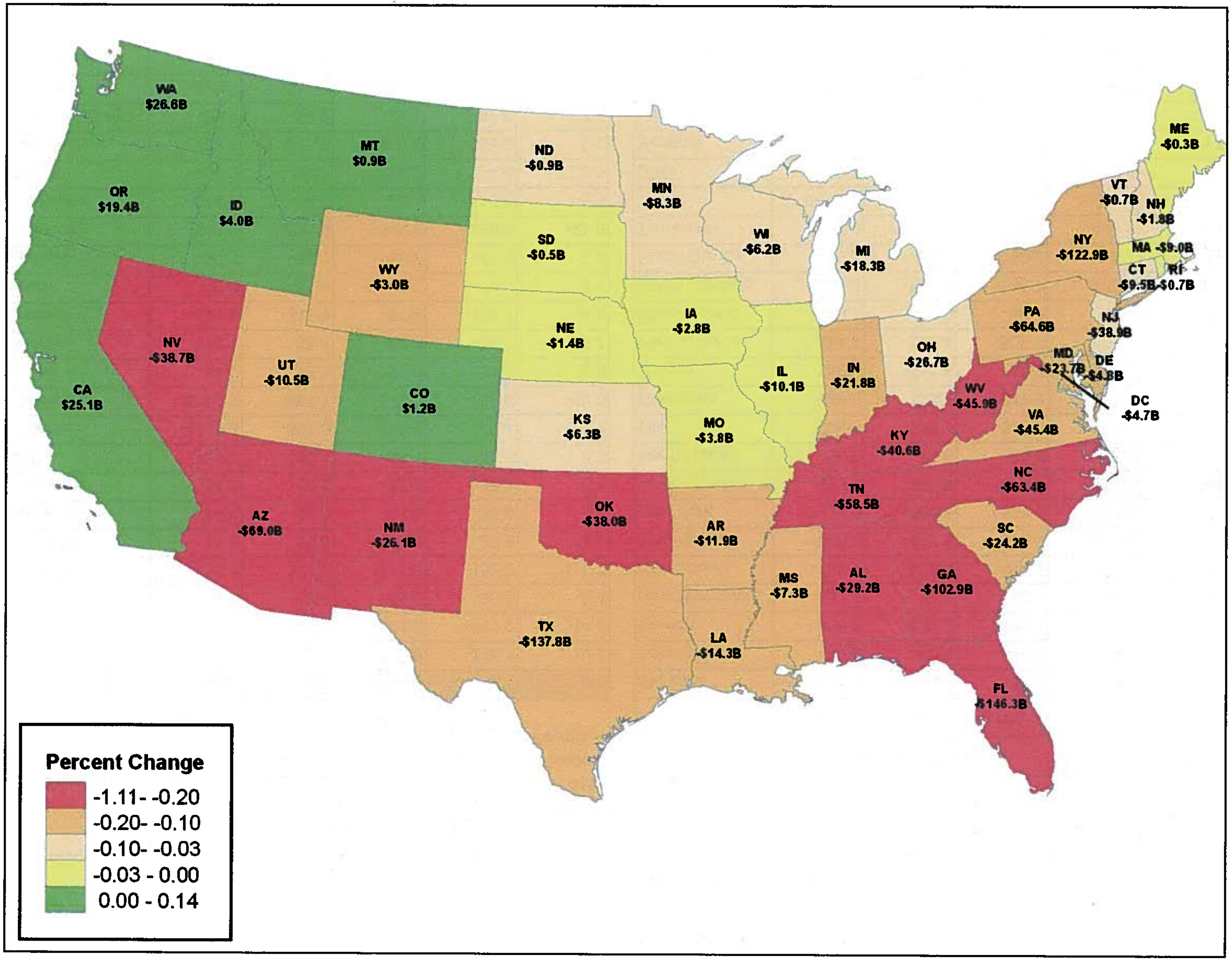

Figure 4-18. GDP risk 0% discount.

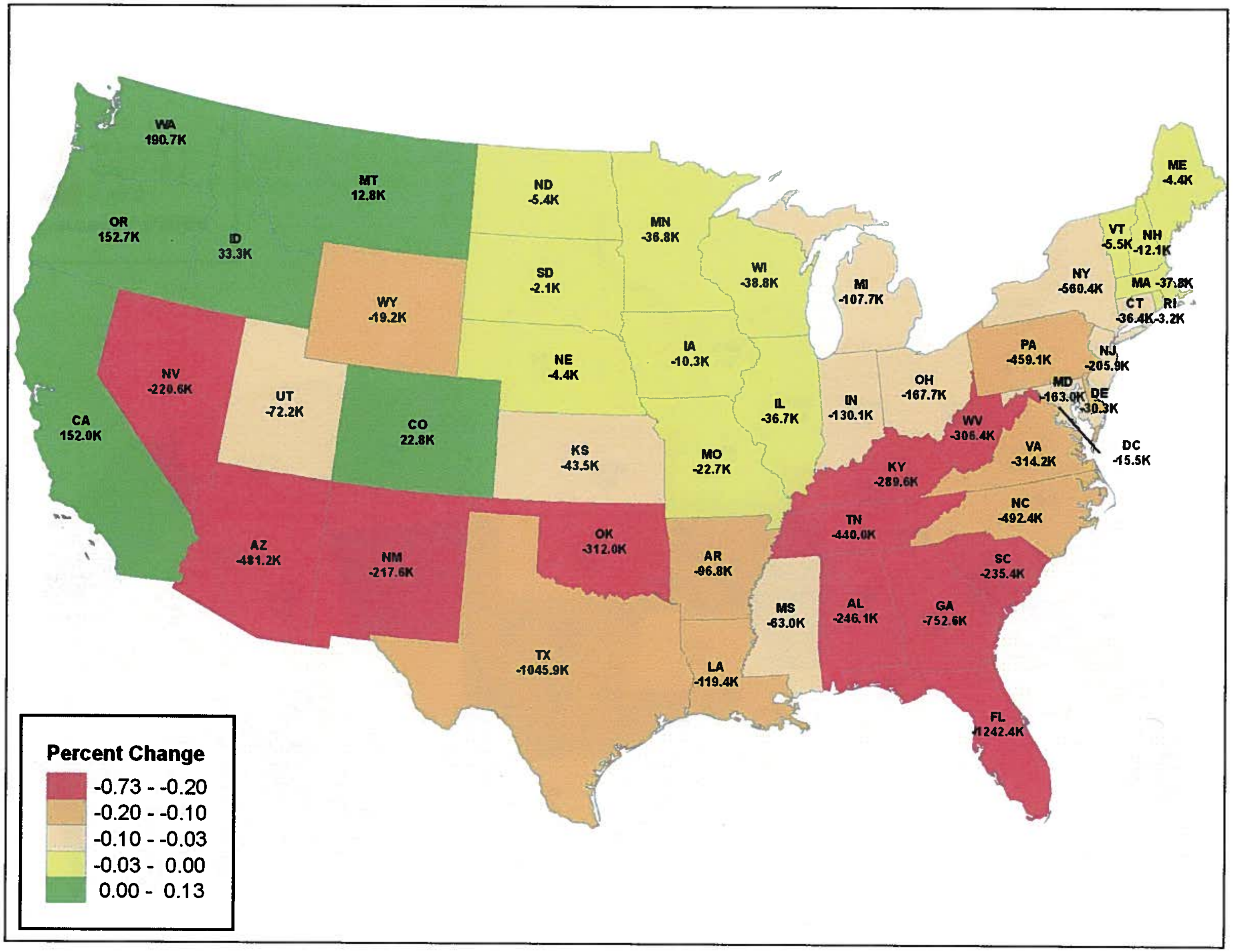

Figure 4-19. Employment risk (employment-years, 0% discount).

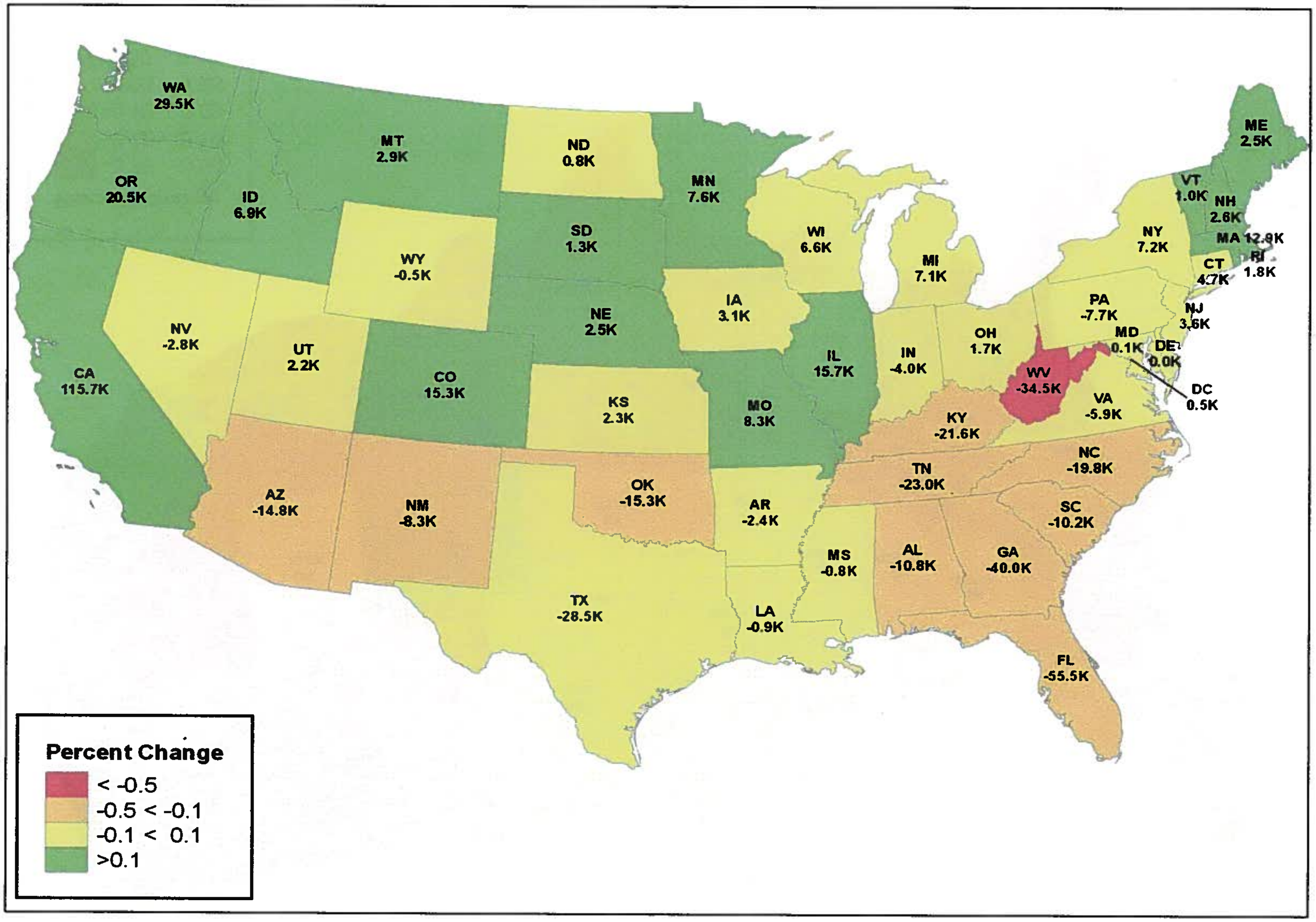

Figure 4-20. Population 2050 risk.

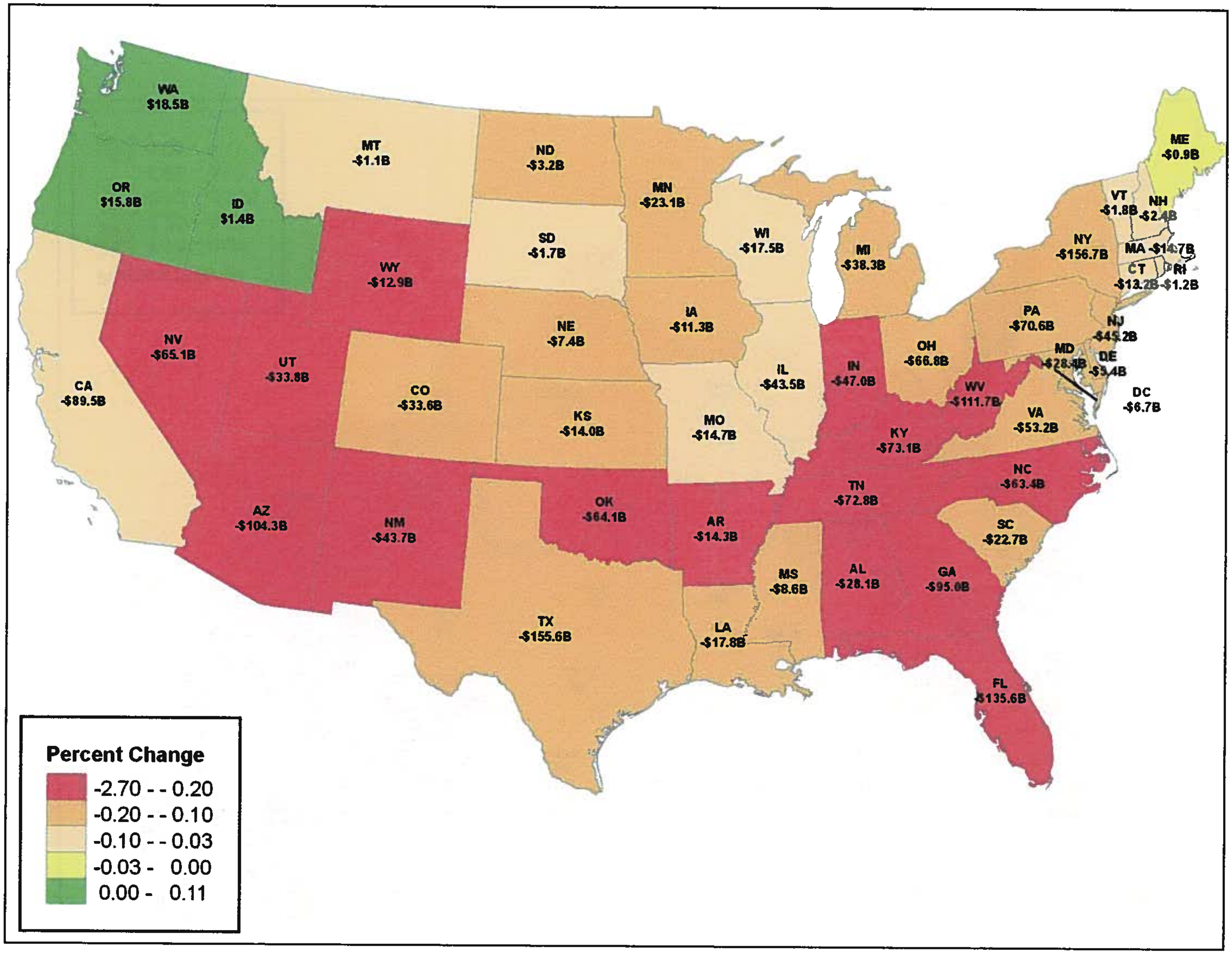

Figure 4-21. Net change in state contribution to GDP 2010–2050, 1% simulation.

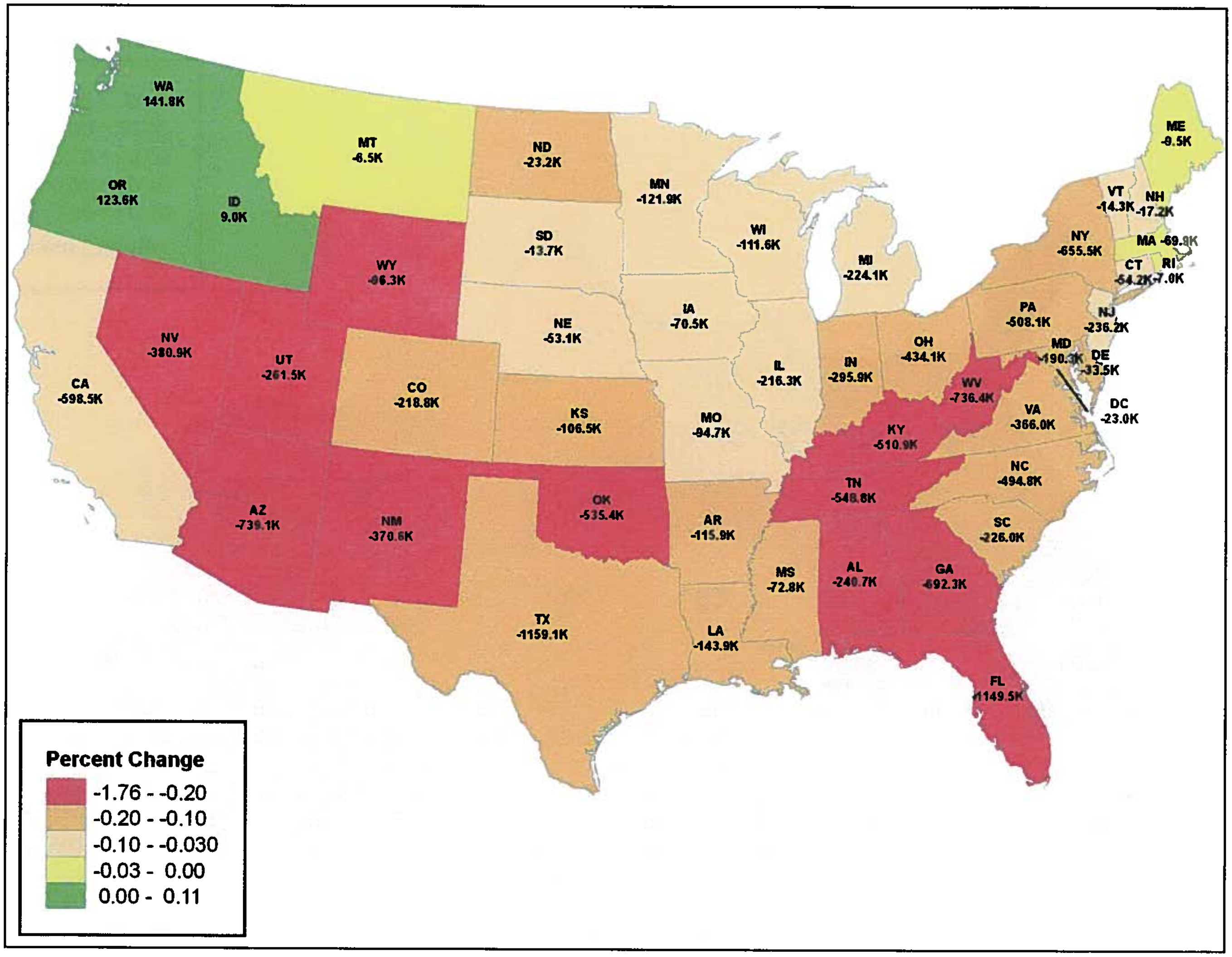

Figure 4-22. Net change in employment-years, 2010–2050, 1% simulation.

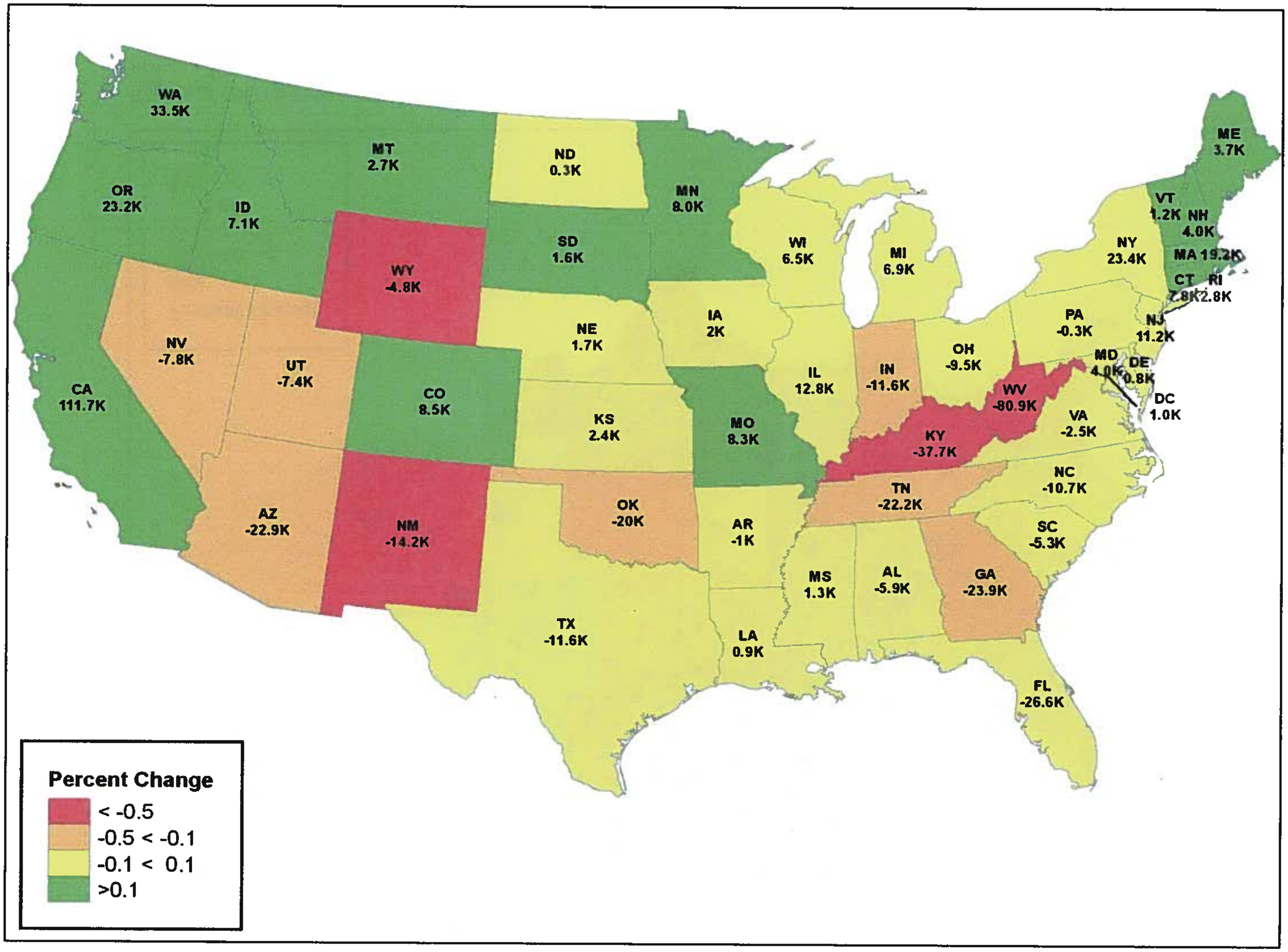

Figure 4-23. Change in 2050 population, 1% simulation.

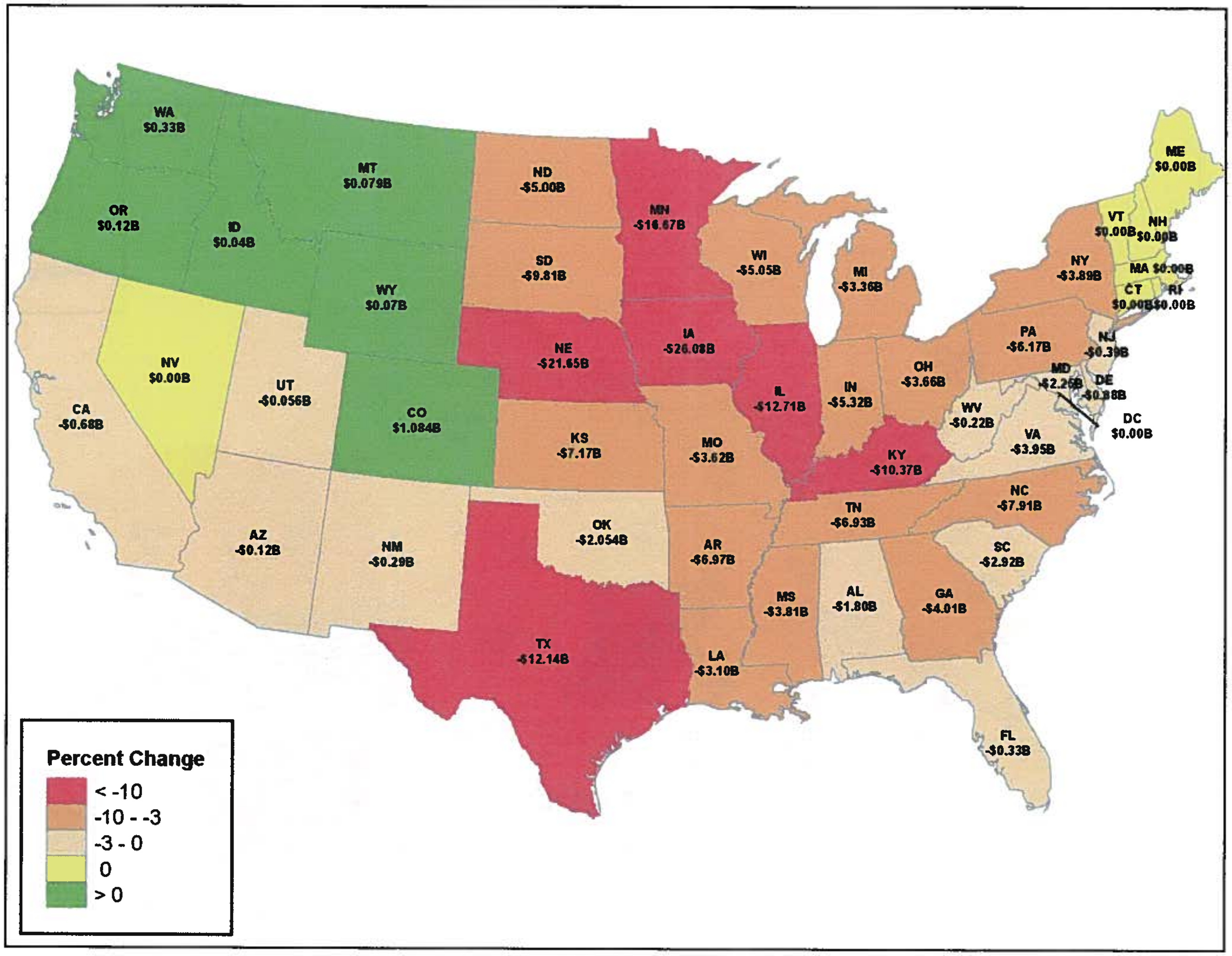

Figure 4-24. Net change in value of corn and soy production, 2010–2050 (states with no recorded production are in white), 1% simulation.

Table 4-9. State-Level Impacts at the 1% Exceedance Probability

1% Case

Region	Change in GDP (0% D.R., $B)	Change in Empl. (1K Labor Yrs)	Change in Pop. (1K People)
United States	-$2,058.5	-12,960.7	0.0
Alabama	-$28.1	-240.7	-5.9
Arizona	-$104.3	-739.1	-22.9
Arkansas	-$14.3	-115.9	-1.0
California	-$89.5	-598.5	111.7
Colorado	-$33.6	-218.8	8.5
Connecticut	-$13.2	-54.2	7.8
Delaware	-$5.4	-33.5	0.8
District of Columbia	-$6.7	-23.0	1.0
Florida	-$135.6	-1,149.5	-26.6
Georgia	-$95.0	-692.3	-23.9
Idaho	$1.4	9.0	7.1
Illinois	-$43.5	-216.3	12.8
Indiana	-$47.0	-295.9	-11.6
Iowa	-$11.3	-70.5	2.0
Kansas	-$14.0	-106.5	2.4
Kentucky	-$73.1	-510.9	-37.7
Louisiana	-$17.8	-143.9	0.9
Maine	-$0.9	-9.5	3.7
Maryland	-$28.4	-190.3	4.0
Massachusetts	-$14.7	-69.9	19.2
Michigan	-$38.3	-224.1	6.9
Minnesota	-$23.1	-121.9	8.0
Mississippi	-$8.6	-72.8	1.3
Missouri	-$14.7	-94.7	8.3
Montana	-$1.1	-6.5	2.7
Nebraska	-$7.4	-53.1	1.7
Nevada	-$65.1	-380.9	-7.8
New Hampshire	-$2.4	-17.2	4.0
New Jersey	-$45.2	-236.2	11.2
New Mexico	-$43.7	-370.6	-14.2
New York	-$156.7	-655.5	23.4
North Carolina	-$63.4	-494.8	-10.7
North Dakota	-$3.2	-23.2	0.3
Ohio	-$66.8	-434.1	-9.5
Oklahoma	-$64.1	-535.4	-20.0
Oregon	$15.8	123.6	23.2
Pennsylvania	-$70.6	-508.1	-0.3
Rhode Island	-$1.2	-7.0	2.8
South Carolina	-$22.7	-226.0	-5.3
South Dakota	-$1.7	-13.7	1.6
Tennessee	-$72.8	-548.8	-22.2
Texas	-$155.6	-1,159.1	-11.6
Utah	-$33.8	-261.5	-7.4
Vermont	-$1.8	-14.3	1.2
Virginia	-$53.2	-366.0	-2.5
Washington	$18.5	141.8	33.5
West Virginia	-$111.7	-736.4	-80.9
Wisconsin	-$17.5	-111.6	6.5
Wyoming	-$12.9	-96.3	-4.8

Obs.: Changes in GDP and employment are summed over the 2010-2050 period; population is the 2050 value.

4.5 Placing the Results in Context

This section contains the national, sectorial, and state-level results of our analysis. It provides an uncertainty-aware estimate of the risk from climate change through 2050 in the absence of policy. These estimates offer a foundation for comparing the benefits of acting to mitigate climate change to the cost of inaction.

The interaction of states and industries means that an impact analysis that considers a state or industry in isolation will miss impacts that could reverse the results. Further, low-probability, high-consequence conditions may dominate the total risk of climate change for states and industries. Some states and industries are affected much more than others. Because of evolving interactions among the responses of states and industries, the impacts of climate change for a particular state or industry can vary in direction (positive or negative) and extent (large or small) from year to year. Similarly, the climatic conditions associated with different exceedance probabilities can produce swings in the direction and extent of impacts over time. States with negative impacts in the "best estimate" (50% exceedance probability) simulation can show benefits in the extreme (1% exceedance probability) simulation. Certainly, the reverse is also true. With diminishing (more extreme) exceedance probabilities, the impact of climate change, in general, sweeps from the Southwest to the Northeast. The relative extent of impacts by state and by the geographical concentration of selected industries shifts with the exceedance probability as climate change moves more intensely across the nation.

The aggregate economic cost in a given state may mask underlying tension. Some sectors, such as agriculture, may experience strong negative impacts while other industries, such as construction, may experience growth. The net reported impact for the state may be strongly positive. In economic assessments, the adaptation to the negative effects of climate change produces new economic activity (i.e., investments) reportable as a benefit. The added costs of the adaptation will generally, however, result in reduced relative competitiveness with associated long-term reductions in economic activity and employment.

The reported summary risk (or total risk) for each state and industry represents the value of mitigating those impacts. The summary risk quantifies the net impact cost of climate change over the full range of possibilities (uncertainty) and consequences. That is why the summary risk also reflects the total risk. It is the value of insuring against those impacts, and it is the economic justification for policy to mitigate them. Risk comes from uncertainty, not certainty. The greater the uncertainty, the greater the risk. *It is the uncertainty associated with climate change that validates the need to act protectively and proactively.*

In the near term, the summary risk at the aggregate national level is less dominated by low-probability events. With the current understanding of climate change through the year 2050, the diversity of resources and climatic conditions across the nation allows adjustments in response to climate change in one region of the nation to partially compensate for those in another region. For the impacts estimated through 2050, the nation as a whole has the resilience to accommodate the impacts "on average." Thus the "best estimate" (average) impacts at the national-level only modestly underestimate the total risk of climate change through 2050.

The results of this study only extend to the year 2050. Impacts beyond 2050 are expected to be exponentially greater, and the results here cannot be generalized to the more severe consequences and more complex impact relationships that may occur in a more distant future. We emphasize summary risk, but some sections of the report do provide added information for 50%, 10%, and 1% exceedance probability conditions. Appendix E shows a very detailed view of impacts at conditions associated with a 1% exceedance probability.

For the present, the impacts and risk noted in this section of the report should help governments and businesses weigh their options for responding to the risk of climate change in the near term. This report provides the cost of inaction. Decision makers can now compare it to the net benefits of any mitigating actions they may pursue.

5 Summary

In this section, we review the primary outcomes, considerations, and limitations of this work. Our purpose is to develop a risk-assessment methodology for dealing with the uncertainty of climate change. To demonstrate this approach, we use the uncertainty in modeled future levels of precipitation associated with climate change as an input to a hydrological analysis that we then use as input to forecast derived macroeconomic impacts. We derive a proxy measure of climate uncertainty from an IPCC climate-model simulation ensemble to drive predictions of the economic cost from climate change for various exceedance probabilities of precipitation. Integration of the cost over the full range of uncertainty represented by this ensemble then characterizes our estimates of the risk from climate change to the GDP through the year 2050.

Our risk assessment only considers the loss in the absence of mitigation or any other climate policy. The value of the loss, on the order of a trillion (2008) dollars for the United States, thus, can be interpreted as an upper limit on how much society could be willing to pay for a successful mitigation of climate change, even over the near term. Consideration of longer-term (post-2050) impacts from climate change would imply a larger cost because of the accelerating climate change, but these more temporally distant impacts are difficult for constituencies to grasp.

The U.S. state-level and industry-level impacts are far from uniform. Some states experience significant swings and large disparities compared to other states. The same lack of uniform impacts is true for industry. Population and employment changes produce similar disparities among the states. Population migration has a significant effect on final outcomes. States that initially experience positive impacts may experience negative impacts in later years, and vice versa.

Conducting an integrated analysis of detailed climatic, hydrological, and economic impacts at the resolution of counties, states, and industries across the range of exceedance probabilities required for a meaningful risk assessment is a relatively complex process. The hydrological and macroeconomic consequences from varying levels of climate change can often defy preconceived notions. This study, however, indicates that the losses associated with the 50% exceedance probability only modestly underestimate the value of the total risk over the full range of exceedance probabilities. This relationship of the 50% exceedance-probability to the total risk is most probably not robust. As advances in climate modeling modify the understanding of best-estimate impacts and the uncertainty characteristics of the climate models, the total risk could be much larger than that associated with the 50% exceedance probability. In the present, this outcome means that current "climate impacts" studies focusing on only the "best estimate" of impacts through 2050 produce national results that can support the policy debate and do corroborate the work here. Nonetheless, states and industries can have impacts dominated by the low-probability, high-consequence tail and by interactions with other states and industries. Consequently, existing "best estimate" studies of individual states and industries can provide useful insights, but an integrated risk assessment appears to be required for a meaningful evaluation of state- and industrial-level risk.

We feel the risk-informed approach used in this work relates physical climate science to the societal consequences and thus directly helps inform policy debate. The integrated process of (1) explicitly recognizing uncertainty in climate-change forecasts, (2) transforming climate-change phenomena into physical impacts that affect economic and societal processes, and (3) converting those physical impacts to time-dependent changes in economic and societal conditions provides the end-to-end assessment capability recommended by the Obama Administration (Holdren 2009). By knowing what aspects of climate change have the most severe human consequences, this type of analysis can also guide and prioritize the scientific research to better quantify the most critical phenomena.

No amount of research can ever eliminate the uncertainty in assessing future conditions and the risks those conditions impose. Because the future may occur before all stakeholders judge that the uncertainty has been adequately reduced, decisions must be made, as they always have been, in the presence of uncertainty. Risk is a function of uncertainty, and the more uncertainty, the more risk. Thus, analyses such as these are required for informing decision making. They support the justification for making decisions because of uncertainty rather than despite uncertainty.

Our detailed, time-dependent approach to the analysis shows the additional early consequences of the volatility in climate change. The impacts across 70 industries and 48 states demonstrate the interrelationships that produce consequences different from those consequences that would be indicated by the analysis of individual states or economic sectors in isolation. To date, this is the first study to address the interactive effects of climate change across the U.S. states and to deal explicitly with the problems of interstate population migration as a consequence of climate change.

Our economic analysis follows the year-by-year impacts associated with year-by-year variability in climatic conditions rather than the more conventional approach of considering gradual change through the years of the analyses. The results of our simulations suggest that the economic consequences of variable global climate change may cause more substantial year-to-year disruptions than climate change would cause if it followed a smooth monotonic trend. A state then lives with those adaptations (and costs) into the future even if climate conditions (temporarily) improve. The added costs often lead to enduring lower levels of industrial output and real disposable personal income beyond what would occur if climate change were a smoothly unfolding process.

We note four primary limiting assumptions in our work. We do not believe they significantly alter our results:

1. A more expansive effort would systematically vary the climate models to establish the key uncertainties relevant to the economic impact analyses. We could include uncertainties associated with the hydrological and macroeconomic models, although that approach would complicate the understanding of how the climate component of the uncertainty affects future risks. Further, a definitive uncertainty analysis of climate models is currently beyond the near-term capability of supercomputing resources and climate science.

2. In this study, we have judgmentally selected water consumption, as opposed to water usage, as the limiting basis for water availability. We also have assumed that legal constraints would dominate supply constraints for the downstream availability of water. Further, we employ a constant proportional relationship between precipitation and water supply. As such, we also have argued that the variation in evapotranspiration due to climate change produces inconsequential second-order effects. A more thorough study could better explore these possible limitations. We believe that the incorporation of such improvements would show the current analysis underestimates the impacts and risks.

3. The technical costs of reducing the water demands of industry and consumers to match the water supply underpin a large part of the macroeconomic analysis. We have based these costs and determined the options available to industry by applying a limited number of studies—studies that were developed for purposes unrelated to the reduced precipitation from climate change. Further, we have used the same unit costs for each state. While we would not expect improved costs to dramatically change the interstate relationships contained in the analysis results, improved costs could alter the total estimated risk from reduced precipitation. Because we have not considered the locational constraints on reducing water usage, such as limitations on the physical space to place equipment, we would expect a more thorough evaluation of technology options to show increased costs.

4. The modeling of the climate risk associated with reduced precipitation must recognize the existence of water rights. Existing water rights, which are based on extensive historical precedence, are fraught with complex legal, political, and social implications. The legal specifics of water rights vary widely from state to state and are unlikely to change dramatically over the analysis time frame. In addition, the allocation of water under enduring climatic water shortages remains largely undefined. Agriculture often has grandfathered rights to water resources, yet under the currently increasing routine instances of limited water availability, compromises, purchases, and the transfer of rights commonly occur. The modeling assumes, to the extent possible, the enforcement of interstate water rights. Thus a shortage in one state, because of defined water allocations, does not necessarily result in a shortage in the downstream state. In this study, we use a simple heuristic when climate change causes reduced water availability. The heuristic assumes that high-value (monetarily and politically) users can purchase rights, but only to the extent where the proportional shortage to other users, such as agriculture or mining, is twice that of the high-value users. The difference in the allocation is associated with payments from the high-value activities to the low-value activities to pay for the water transfer.

Despite the limitations of the current work, we feel it does establish a process for improved and more-meaningful risk assessments of climate change than is currently present in the literature. For the future, we believe that what is more important than refining state-level hydrological conditions and adaptation costs is determining the risks from climate change on international strategic supply chains and the stability of linchpin nation-states. The consequences of climate change for these issues may affect U.S.

interests more than the internal U.S. response to climate-change phenomena. We are pursuing these concerns in our follow-on work rather than directly extending this study.

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Appendix A. Hydrological Modeling

The hydrological model used in the study was adapted from modules embedded in the broader decision-support framework for integrated energy-water planning and management depicted in Figure A-1 (Tidwell et al. 2009). The formal name of this Sandia product is the Energy Water Model. The model was originally developed to study future water usage in the Rio Grande Valley of New Mexico. It has subsequently been enhanced to more completely address climate-change issues, and its geographical data set has been expanded to accommodate the entire United States. In this study, we use elements of the model that pertain to the simulation of future water demand as well as to the identification of regions of potential future water stress. These simulations are possible at each of four reference scales: national, state, county, and watershed.

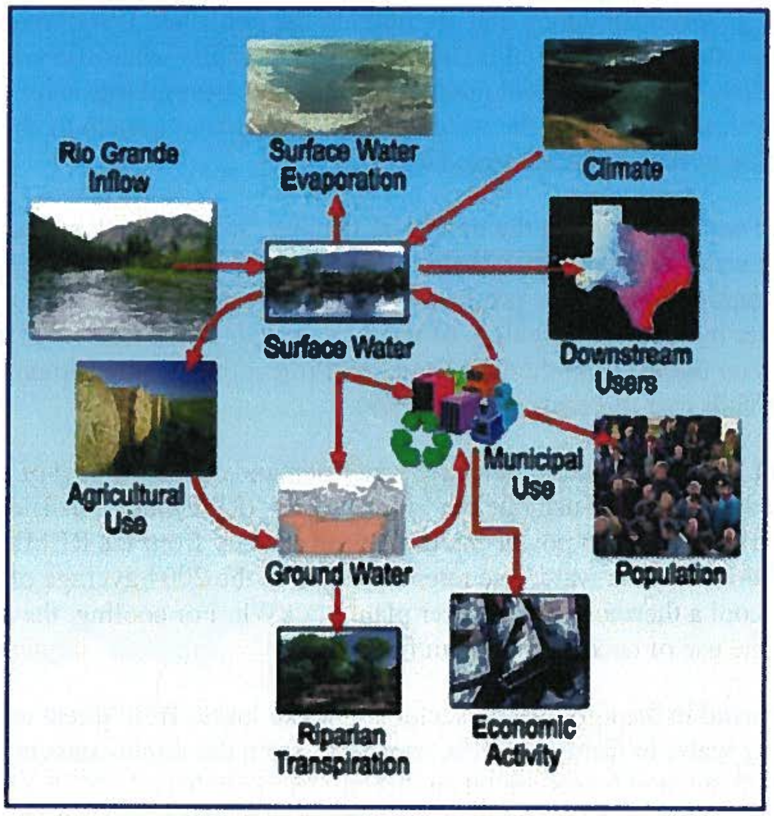

Figure A-1. The Sandia hydrological model (subset of modules used for this study).

We calculate water demand individually for six different use sectors: municipal (including domestic, public supply, and commercial), industrial, electrical power production, agriculture, mining, and livestock. Water use and water consumption are tracked separately for each of these sectors, as are the resulting return flows. Water use denotes the temporary withdrawal for some purpose, such as cooling, and then returning the water to its source, such as a river, for future use by downstream entities.

Consumption denotes a withdrawal of water, such as for crop irrigation and soft drink production, where it becomes unavailable for other purposes. Statistics of water use published by the U.S. Geological Survey (USGS) serve as the primary data source for the analysis. Specifically, data from the 1985, 1990, and 1995 campaigns provide the most comprehensive picture of water use in the United States and hence form the calibration and initialization basis of this analysis (USGS 2009).

We model municipal water use and consumption at the county level and subsequently aggregate these data to the state level. The values for water use in 1995 serve as the initial conditions for the model. The analysis for this study begins in 2000. Future rates for water use and consumption are calculated as the product of the per capita water use and consumption and the population. Projections of population change for individual states are based on output from our macroeconomic referent (the REMI model), whereas the per capita rates for water use and consumption are extrapolated according to regression equations that are fitted to the published USGS rates for water use and consumption. The maximum change in the per capita water use and consumption is capped at ±20% simply to reflect the fact that changes beyond this level generally require the physical structure of the water supply and demand system to change beyond what the existing system can accommodate.

We derive water demand in the industrial, mining, and livestock sectors in a fashion similar to how water demand is handled in the municipal sector; however, we calculate use and consumption rates as the product of the gross state product (GSP) and the associated water intensity (e.g., gallon of water per dollar of the GSP). Projections for the GSP are based on output from the REMI model. Projections of water intensity are based on historical trends and forecasts (USGS 2009).

We model increases in thermoelectric water demand as the product of new power-plant capacity and the water-use rate per kilowatt-hour (kWh). For consistency, we take projections of new growth in power-plant capacity directly from the REMI model. We assume that thermoelectric water-use rates are equal to the 2004 average of the amount of water need to cool a thermoelectric power plant per kWh. For cooling, the model distinguishes the use of ocean water from fresh water.

Water demand in the agricultural sector considers losses from direct use at farms and from conveying water to farms or fields, as well as from the direct consumptive use of the crop itself. Estimated losses are taken directly from published USGS data. We calculate the consumptive losses from crops as the product of historical average irrigation rates for specific crop types and the associated irrigated acreage (USDA 2008). Thus, for each crop considered, we multiply the amount of acre-feet of water used for irrigation of the crop times the average number of acres farmed of the crop.

Key to this analysis is determining at what point a region will begin experiencing water stress. That is, at what point will the available water supply be insufficient to meet all projected water demands? This determination requires some measure of the available water supply. However, detailed current water-supply values for each region of the United States are unavailable, and calculating these values is well beyond the scope of this study. As such, we use a proxy to water supply that is based on the long-term mean (average) gauged flow data, which are available at the USGS four-digit hydrologic unit classification level (Stewart et al. 2006). The long-term averages for the regions are further modified by sequentially subtracting increases in consumptive water use from upstream basins (to account for the effect of growing water use on the availability of water). The model includes projections on the use of ground water and implicitly considers jurisdiction rights on downstream water usage. For this analysis, the ratio of runoff to precipitation is assumed to be adequately constant for determining water availability. Although studies indicate that there will be a change in this ratio, the statistics remain inconclusive about the amount of change (Sheffield and Wood 2008; Seager et al. 2008). Further, any such change in the ratio of runoff to precipitation is inconsequential relative to the impacts considered in this study, as previously noted in Section 2.6 of the main text.

To project potential water stress at the state level, the model calculates the ratio of water supply to projected demand. Three thresholds are used to determine the potential water stress of the individual states based upon the categorization scheme presented in Table A-1. If the ratio of water supply to projected demand is less than 2 (i.e., the water available is less than twice the amount of water needed), the state is assumed to be using essentially as much water as is available in a normal year. Thus, any new water use or drought would immediately result in a water shortage for the states (Taylor 2009) in the "Current < Normal" category, i.e., Arizona, California, Nevada, and New Mexico. If the ratio of water supply to projected demand is between 2 and 10, the state is assumed to experience a water shortage whenever the supply drops below 60% of the long-term average. States subject to this threshold are listed in the category named "Current < 60% of Normal." Finally, all other states are assumed to experience shortages only when the water supply drops below 40% of average and are listed in the category named "Current < 40% of Normal."

Table A-1. Water-Shortage Thresholds by State

Current < Normal	Current < 60% of Normal	Current < 40% of Normal
AZ	CO	AL
CA	CT	AK
NV	DE	AR
NM	FL	DC
	GA	HI
	KS	ID
	MA	IN
	NE	IA
	NJ	KY
	NC	LA
	OK	ME
	RI	MD
	SC	MI
	TX	MN

Current < Normal	Current < 60% of Normal	Current < 40% of Normal
	UT	MS
	VA	MO
	WY	MT
		NH
		NY
		ND
		OH
		OR
		PA
		SD
		TN
		VT
		WA
		WV
		WI

The three categories in Table A-1 relate to the states' current capabilities for storing water. The states in the "Current < Normal" category generally have considerable water-storage capacity, typically in the form of dam systems that can accommodate significant fluctuations in precipitation. States in the "Current < 60% of Normal" category typically have less storage capacity in place. Those states in the "Current < 40% of Normal" category seldom have storage capacity capable of accommodating drought conditions. For each year, climate data are passed to the hydrological model for it to determine where water stress will occur. Where precipitation ratios (current/normal) fall below the above thresholds, apparent water shortages are indicated. Shortages are not evenly distributed across the sectors, but rather are weighted more heavily toward agriculture, mining, and livestock. Specifically, two-thirds of the proportional water-shortage burden lies in agriculture, mining, and livestock, where each is administered according to its relative share of the demand. These shortages are calculated as a ratio of desired water use compared to available supply for the sector. This availability is passed to the REMI model for evaluation of the economic impacts.

The impacts of water availability on crop yield are calculated within the hydrological model. These yield calculations are based on a model developed by McCarl et al. (2008). The hydrological model is empirically based on the historical impact of climate changes of the crop yield distribution, considering temperature, precipitation, variance of intra-annual temperature, a constructed index of rainfall intensity, and the Palmer Drought Severity Index (PDSI). For our analyses, these data are available or derivable from the climate-model results within the PCMDI data set discussed in the main text. We assume that rainfed crops depend solely on precipitation, while irrigated crops depend on both irrigation and rainfall. Specified precipitation and temperature conditions come directly from the climate model, while the percentage of irrigation is based on the severity of water shortage in the individual states.

Visit https://waterportal.sandia.gov/modelingteam/energywater/Models for further information on the Energy Water Model.

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Appendix B. Economic Impact Methodology

The material in this appendix is derived from Warren et al. (2009). The economic impact methodology was designed to answer two economic questions:

1. What does a physical climate change mean economically?
2. How can this change be incorporated in a macroeconomic model?

To answer the first question, we use the forecasts of hydrological changes reported by the Sandia hydrological model noted previously. Table B-1 lists the types of hydrological changes forecast by this model; each of these annual variables is forecast by U.S. state over the 2010 to 2050 period.

Table B-1. Variables Used to Report Hydrological Impact Forecasts

Variable	Description
$\alpha^i_{x,t}$	Relative production (compared with a base year) for crop x (both irrigated and nonirrigated crop production, combined)
H^i_t	Fraction of normal water availability for municipal consumption
E^i_t	Fraction of normal water availability for thermoelectric generation consumption
HP^i_t	Fraction of normal hydroelectric power production
I^i_t	Fraction of normal water availability for industrial consumption
M^i_t	Fraction of normal water availability for mining consumption

As described in the sections below, we translate these hydrological impacts to direct economic impacts by developing a set of assumptions about the direct economic impacts of each, model these impacts, and then use publicly available data to quantify the actual direct economic effects. We then enter these direct effects into the REMI model to estimate the total (direct plus indirect) economic impacts over the 2010 to 2050 period.

B.1 Climate-to-Economy Modeling Assumptions to Address Uncertainties

This study does not exogenously adjust the technological assumptions inherent in the base-case forecast of the REMI model. Additionally, the study maintains the REMI price-elasticity relationships that simulate consumer responses to rising prices. In general, this response implies substitution of less-efficient production technologies for the use of more-efficient production technologies within the economy. For example, the elasticity relationships do implicitly capture the substitution of incandescent lighting for fluorescent lighting and the purchase of high-efficiency appliances, but these consumer behaviors are economically motivated. We do not adjust the elasticity relationships to include any additional altruistic behaviors to avoid climate change.

To translate each hydrological change into a direct economic impact, we make a set of economic assumptions, models, and calculations based on the type of change and the sectors in which these hydrological changes occur. Each sector is described below, in turn, beginning with two assumptions that apply across all the nonfarming sectors. These assumptions simplify the economic methodology and reduce the uncertainties.

1. For inland facilities, we assume that investments can be made quickly as conditions warrant, such as imposing close-cycle cooling systems or even dry cooling. We further assume that these modifications could happen without the significant shutdown of capacity. States that are adjacent to oceans will have access to desalinated water.

2. Retrofits to conserve water are made instantly. In reality, there may be some delays in producing machinery for the retrofits, which could lead to short-term shutdowns of facilities in the various sectors. We assume that these shutdowns will likely be relatively minor and that postretrofit production can largely compensate for production reduction during the shutdown. Thus, we ignore the cost impacts form the shutdown itself.

B.2 Modeling Agricultural Impacts

To model the effects of changes in agricultural productivity on the U.S. economy, we develop separate strategies to estimate the impacts to (1) farm industries and their suppliers and (2) nonfarm industries that use farm outputs as inputs to their own production.

B.2.1 Impacts to Farming Industry

As with all of the climate-to-economy modeling, the estimates of direct economic impact need to be quantified information (i.e., variables) that can be input directly into the REMI model. The REMI model does not endogenously (i.e., internally) simulate farming activity,[15] but it does include a translator module that allows users to model impacts to sectors that are not explicitly captured in the model, such as the farming sector. For each state and year in the simulation period, the translator module takes as an input the change in the total value of production for that industry and "translates" it into impacts to a broader set of industries. For farm industries, the translator module

[15] This assumption is inherent in the REMI model. It may be justified economically because a principal factor in agricultural production is land, which—unlike capital or labor—is immobile. Furthermore, agricultural markets are international in scope. Thus much of the supply and demand and agricultural markets is largely exogenous (i.e., external) to the United States.

calculates estimates of the changes in government spending, farm employment, farm compensation, and intermediate demand to 65 other industries within the particular state. These translated variables are then used as the inputs to the REMI model. The reduction in output is based on the change in agricultural productivity coming from the hydrological model discussed in the previous appendix.

B.2.1.1 Modeling Assumptions

Given that the farming industry is complex and that behaviors of individual farmers depend on a wide range of factors that are hard to capture with the REMI translator module, we make a number of simplifying assumptions:

- The climate-based changes in hydrology only impact agricultural production in the REMI model for the combined irrigated and nonirrigated crops as forecast separately by the Sandia hydrological model. We do not, for example, incorporate price-based decisions made by farmers to produce or not produce crops. The hydrological model implicitly contains the many physical factors and human factors (e.g., differences in fertilizer applications due to fertilizer prices, different water availability for irrigated versus nonirrigated land), and these models incorporate some factors like soil productivity and, to some extent, farmers' decisions about when to apply fertilizer and how much fertilizer to apply based upon changes in rainfall.

- The changes in corn and soybean production are considered representative of cereal corps. Corn and soybean farming have the greatest shares of production. According to the National Agricultural Statistics Service, in 2008 the production of corn for grain was \$47.4 billion, and the production of soybeans was \$27.4 billion. By comparison, the production of all "field and miscellaneous crops" was \$134 billion, the production of "34 major vegetables" was \$10.4 billion, and fruit production was \$16.5 billion (USDA 2009a). The third largest crop is hay (\$18.8 billion), whose productivity is not modeled within the Sandia hydrological model. Changes to crops other than cereal crops are neglected, but the combined change in the corn and soybean productivity is used as a proxy for productivity in all farming inputs.

- Absolute and relative crop prices are held at constant world prices over the time frame of the analysis. Agricultural commodity prices actually fluctuate on a day-to-day basis based on events in world commodity markets. By affecting agricultural productivity, global climate change will affect global commodity prices. It is uncertain how the international markets for agricultural commodities will respond to global climate change.[16] Because our analysis is strictly U.S. centric, we assume that relative global prices do not change. Local U.S. agricultural prices can change as costs change.

[16] A global model of how agriculture changes its productivity in response to climate change may provide a better idea of whether agricultural commodities will become more or less expensive. Even with such a model, many factors remain that will lead to substantial uncertainty about the overall effect of climate change on commodity prices.

- The only agricultural and water-use substitutions applied in the economic analysis are those substitutions predicted within the hydrological model. No additional substitutions are made on the economics portion of the modeling. In reality, there is a wide range of substitutions that are made by individual farmers, for example: farmers often rotate crops, farmers may change the mix of crops in response to price changes or expectations in productivity, farmers may install irrigation systems or choose not to use existing irrigation systems, and farmers may alter the timing of plantings and fertilizer applications. These considerations are implicitly recognized within the Sandia hydrological model based on historical responses. For this analysis, however, the land in cultivation does not change with climatic conditions. The estimates of the production loss in agriculture due to climate change come from within the Sandia hydrological model. The REMI analysis considers the reduction in production to be the dominant impact. Any additional changes that are outside the scope of this effort are assumed to be secondary.

- We use the exogenous growth pattern for advances in agricultural production technologies that is used in the base case of the REMI model (our macroeconomic referent). In addition to improvements in general framing practices, these changes consider improvements in how intermediate goods and services are used in the production of crops. These improvements over time are applied by the translator module when it converts the agricultural results of the hydrological simulations into input changes to the REMI model. The ratio of the corn and soybean contribution to the GDP to the production of these crops is therefore assumed in the climate-change simulations to grow at the same rate as the REMI model's base-case forecast. For example, if a farmer in the base case produces a bushel of corn in 2050 with half the amount of labor used in 2010 (based on REMI's base-case forecasted improvements), a farmer in the simulations will produce a bushel of corn in 2050 with half the amount of labor used in 2010 even if fewer bushels are produced in the simulations than in the base case. Effectively, our assumption implicitly considers the ratio of the farm GDP to farm production to remain unchanged from what it is in the REMI base case for all our simulations.

- We assume that climate change does not directly affect livestock farming. In reality, livestock farming may be impacted by changes in the price of feed, changes in the productivity of forage eaten by grazing livestock, and water used in livestock farming and manufacturing.[17] Industrial livestock production may be affected indirectly through impacts to the food manufacturing industry. The hydrological model does capture these phenomena, but we consider the impacts secondary to this analysis.

- We do not make adjustments for the effect of climate change on forestry. While it is likely that climate change will affect forest productivity, given the long time constants in silvaculture and the 2050 time horizon of this study, the important impacts on the forestry industry (other than increases in fire destruction, also neglected) occur in time frames beyond this analysis.

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[17] Water use in livestock farming is less than 1% of all U.S. water use (Hutson et al. 2004).

B.2.1.2 Modeling Procedures

Because the output of the translator module is proportional to the magnitude of the inputs, we used the translator to develop a standard set of impacts for a $1 million change in the corn or soybean crop production. We can then determine the impact from any change in farm production by simply multiplying the farm loss in millions of dollars by the "standard set." This linear approximation, which essentially employs a set of multipliers, allows automated calculation of inputs to REMI agricultural-sector based on the output of the hydrological analysis.

We use estimates of corn productivity from the Sandia hydrological model to estimate changes in the REMI model's grain-farming industry and changes in soybean productivity in the REMI model's oilseed-farming industry. Changes in production values (measured in dollars aggregated across each state) for each crop, x, (that we have entered into the REMI model via the translator module) are calculated as

$$\Delta Y^i_{x,t} = Y^i_{x,t} - Y^i_{x,b} = (\alpha^i_{x,t} - 1) Y^i_{x,b} \frac{GDP^{farm}_t}{GDP^{farm}_b},$$

where

$\Delta Y^i_{x,t}$	=	the change in production for crop x in state i (an average of 2006 to 2008 data [USDA 2009a],[18]
$Y^i_{x,t}$	=	the value of production in year t,
$Y^i_{x,b}$	=	the average production in the baseline period (an average of 2006 to 2008 data [USDA 2009a]),
$\alpha^i_{x,t}$	=	the relative production of crop x in year t in state i to the baseline production (an output of the hydrological model),
GDP_t^{farm}	=	the REMI model's (exogenous) forecast of national farm GDP in year t, and
GDP_b^{farm}	=	the REMI model's (exogenous) forecast of national farm GDP in the baseline period (an average of 2006 to 2008).

To quantify the input variables that can be used to simulate the impacts, we convert $\Delta Y^i_{x,t}$ to millions of dollars and multiply that value by the variables produced by the REMI translator module for each state, economic sector, and year in the forecast period.

[18] Taken as the average of 2006 through 2008 data (USDA 2009a) .

B.2.2 Impacts to Industries That Use Farm Output

In addition to directly impacting agriculture, changes in agricultural productivity will impact the downstream users of agricultural farm output. These users are modeled directly within the REMI model except for the intermediate inputs they purchase from the exogenous farm industry.

B.2.2.1 Modeling Assumptions

Modeling the effects on the downstream users of farm products in this study requires a number of assumptions in addition to those listed above:

- The actual amount that the users of a commodity pay to obtain the commodity includes the cost of transportation. Although this "economic geography" process is modeled in most industries within the REMI model, once again it does not apply to the exogenous farm industry. In this case, the net price of these food commodities is assumed to include transportation costs. If production in a state decreases, net prices are assumed to increase due to the higher costs necessary to transport the commodities.

- We assume that the degree to which an industry is affected by net price changes of farm production is proportional to the total requirements of the particular industry that originates from the farm industry. Table B-2 lists the Bureau of Economic Analysis (BEA) industries that have total requirements of $0.05 or more for each dollar of production, an amount that was chosen as the cutoff for industries modeled in this study. Changes in the net price will change the production costs for the industries shown in the right column of the table. The data in the table were extracted from U.S. Department of Commerce (2008b).

Table B-2. Industries with Total Requirements from Farms of at Least $0.05 per $1 of Output

IO Code	BEA Industry Name	Requirement for $1 Output (R_x)	REMI Industry/Industries
111CA	Farms	$1.18	N/A
311FT	Food and beverage and tobacco products	$0.31	#19: Food manufacturing, #20: Beverage and tobacco product mfg.
113FF	Forestry, fishing, and related activities	$0.10	#2: Agriculture and forestry support activities; Other
722	Food services and drinking places	$0.07	#62: Food services and drinking places

- We assume that changes in corn and soy production, when averaged together using a weighted average based upon baseline production of the two crops by state, serve as proxies for changes in productivity for all farm inputs within a state.

- To estimate the direct GDP contribution of crop production, we estimate the ratio of the GDP directly due to crop production to production of corn and soybeans. Between 2006 and 2008, national corn and soybean production averaged $58.1 billion (2000$) and crop production averaged $126 billion (USDA 2009a). During the same time, the average estimated (exogenous) farm GDP in the REMI model was $87.9 billion. In 2006, the measured output in livestock was $112.1 billion) (Figueroa and Woods 2008). Therefore, the estimated ratio is [$126.0 billion/($112.1 billion + $126.0 billion) * $87.9 billion]/$58.1 billion = 0.801.

- The REMI model's projected changes in technology in industries that use farm products as inputs account for the REMI model's forecast changes in food-production technologies. Therefore, only the changes in productivity measured by the hydrological model (i.e., not the REMI model's forecast increases in farm productivity) are used to calculate changes in production costs.

- Final demand from consumers for farm output is small (personal consumption expenditures are $52.9 billion compared with industry output of $294.8 billion). Most consumer demand for farm production comes by way of demand for the production of the industries listed in Table B-2 (e.g., personal consumption expenditures for food and for beverage and tobacco products are $482.5 billion compared with industry output of $722.2 billion and personal consumption from food services and drinking places is $497.8 billion compared with industry output of $614.1 billion (U.S. Department of Commerce 2008b). Therefore, we do not model changes in the net prices of farm production that directly affect consumers although we recognize that the REMI model endogenously (i.e., internally) calculates rising prices to consumers from cost increases in these other industries.

B.2.2.2 Modeling Procedures

Because farm production is a basic input for most of the production in the industries listed in Table B-2, it is difficult to substitute other inputs. An increase in the net costs of farm production will appear to be an exogenous increase in production costs in these industries (because the farm industry is not modeled endogenously in the REMI model). Therefore, we model the increased net costs to these industries by exogenously increasing the production costs in the REMI model. This approach is "used when a specific policy will affect the cost of doing business in a region without directly changing the relative costs of factor inputs" (REMI 2009). Farm input is not included as a factor input in the REMI model.

We assume that if farm production within a state changes, the changes are compensated by imports or exports via rail transportation. Table B-3 gives some average costs of shipping grains by rail, as well as the price of each crop. The "% Rail" column indicates the cost of the rail transportation relative to the price and can be thought of as the increase in net price if a firm had to obtain these grains via rail instead of locally. With these data as a guide, we assume that production costs will increase or decrease by a factor of 20% of the decrease or increase of agricultural production in the state.

Table B-3. Average Cost to Ship Grain by Rail[19]

Grain	Avg. Rail Cost Per Bushel	July 2010 Price Per Bushel	% Rail
Corn	$0.99	$4.75	21%
Soybeans	$1.04	$9.87	11%

We use the following equation to estimate the change in production costs caused by changes in agricultural production in state i:[20, 21]

$$\Delta PC\%^{i}_{x,t} = -20\% * R_x * \left(\frac{(\alpha^{i}_{corn,t} - 1) * Y^{i}_{corn,b} + (\alpha^{i}_{soy,t} - 1) * Y^{i}_{soy,b}}{Y^{i}_{corn,b} + Y^{i}_{soy,b}} \right),$$

where

$\Delta PC\%^{i}_{x,t}$ = the percentage change in production costs for industry x,

R_x = the total requirements of industry x for farm products to produce a dollar of outputs,

$\alpha^{i}_{x,t}$ = the relative production of crop x in year t in state i to the baseline production (an output of the hydrological model), and

$Y^{i}_{x,b}$ = the average production in the baseline period (an average of 2006 to 2008 data [USDA 2009a]).

The term $\Delta PC\%^{i}_{x,t}$ goes into the REMI model as the change in the shares of production costs for the appropriate industry.

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[19] The data in the table were compiled from USDA (2009b), the July 2010 futures price (closing price on 5/19/2009 on the Chicago Mercantile Exchange, http://www.cmegroup.com, and calculation of the rail costs as a percentage of the futures price.

[20] In states without either corn or soybean production, this term is assumed to be zero.

[21] Throughout the report, the "*" symbol denotes element-by-element multiplication.

B.3 Modeling Impacts to Municipal Water Use

Municipal water use is one output from the Sandia hydrological model that we do not model directly in the economics model (i.e., REMI) because our internal evaluation indicates that there are many opportunities for substantial municipal water conservation that will be inexpensive and have little effect on the livability of a region. While there is a utilities sector within the REMI model that subsumes the municipal water utilities, municipal water utilities are not modeled explicitly in the 70-sector version used in this analysis. As such, directly calculating the impact of a separate municipal water sector is not possible. Therefore, a number of assumptions need to be made to model the effects of water shortages to municipal water utilities. These assumptions follow.

B.3.1 Modeling Assumptions

- Our review indicates that drought-induced water conservation is relatively easy to conduct. For example, the EPA estimates that 30% of household water is used for outdoor watering (and this is higher in arid regions) (EPA 2008), suggesting that a significant fraction of water consumption would be eliminated in time of drought. Also, the American Water Works Association (2009) estimates that 30% of household water could be saved if all homes installed common water-saving features. Finally, 60% (or more) of household water use could be readily reduced with current, affordable technology.

- Our review indicates that municipal water losses of greater than 60% would have to be made up with more-extreme conservation measures, such as developing new no- or low-water technologies, or increased conservation measures, such as taking shorter showers, washing clothes less frequently, using disposable dishware, eliminating car washes, closing golf courses, or having the population migrate to states with greater water availability.[22]

- Our review indicates that many technologies exist that may help provide long-term sources of municipal water. For example, rain-harvesting technology, water treatment, desalination, and water pipelines could be used to increase supply. We assume that the use of future technology remains the same as today except that desalination may be increased near the coasts. The assumed use of conventional water-conserving technologies is a pragmatic approach to estimating the impacts of reduced water availability.

[22] As for minimum water requirements, the United States Agency for International Development (USAID) recommends 20 to 40 liters per person per day, while a separate study recommends a Basic Water Requirement right of 50 l/p/d (17% of average U.S. household use and 9% of average California household use) (Gleick 1996). The daily per-person minimum requirement of water usage could probably be reduced by more-efficient technologies like composting toilets.

B.4 Modeling Impacts to Power Production

Although agricultural irrigation has the largest consumption of water, thermoelectric power production is the sector with the largest U.S. water usage (Hutson et al. 2004),[23] albeit with only 3% of the national consumption (Feeley et al. 2005). As a result, water shortages could be expected to have significant impacts on electricity supplies. In the total absence of water, facilities could maintain production by dry cooling, thereby eliminating water consumption in thermoelectric generation. New renewable-generation technologies such as wind and photovoltaic facilities would also not need water. In states adjacent to oceans, desalinated water used in evaporative cooling systems and ocean water used in once-through cooling systems provide an even cheaper alternative. To reflect the increased costs of the backstop technology, we model the effect of water shortages on electricity production by increasing the costs of generating electricity in the REMI model.

Additional impacts to power production result from changes in water volumes in rivers and streams that change the available production of hydroelectric power. We model these changes by changing the demand for alternate sources of electricity production in the REMI model.

B.4.1 Thermoelectric Power in States not Adjacent to an Ocean

Because of prohibitive costs, in-land power plants do not attempt to use ocean water and therefore need to reduce their dependence on water availability (e.g., river flow) conditions.

B.4.1.1 Modeling Assumptions

- Thermoelectric power was responsible for 48% of water withdrawals in 2000 (Feeley et al. 2005). However, much of that water (91%) is used in once-through cooling, where most water is returned to the source where it originated, at a higher temperature, and thus is not consumed. The remainder of the water is used in closed-loop cooling systems where most of the water is evaporated, hence consumed. We use this basis to distinguish water consumption from usage, as we incorporate investments to reduce the water needs of the power sector.

- Due to climate change, it is possible that some freshwater sources for once-through cooling will no longer have a sufficient flow of water. Hydroelectric power may be similarly affected by reductions in water flow. We assume the reduced hydroelectric production may necessitate additional supplies of power from alternate sources such as thermoelectric power. We include the impact of developing the alternative production facilities.

- Climate change may also increase the temperature of water and air, which may decrease the cooling efficiency of thermoelectric power plants. Additionally,

[23] Consumption is higher in agriculture because 91% of thermoelectric withdrawals are used in once-through cooling, which consumes very little water.

"warmer water discharged from power plants can alter the species composition in aquatic ecosystems" (Karl et al. 2009). Because the temperature changes in river water are not explicitly considered by the Sandia hydrological model, we do not explicitly consider the economic effects of these changes for the power plants. As noted in Section 2.6, the impact of the changes in efficiency of the power plants is small compared with the cost increases already assumed by retrofitting the cooling system.

- In addition to once-through cooling and closed-loop cooling, there is a third type of cooling referred to as air-cooled (dry) cooling. This expensive but universally applicable technology to combat water shortage is called the backstop technology. This technology consumes little water, and instead works similarly to air cooling by removing heat from steam and transferring it to the ambient air with fans. We assume that electricity producers will retrofit to dry cooling only when that are faced with water shortages, A large portion of thermoelectric power generation involves converting to combined-cycle generation technologies (Powers Engineering 2006), much of which can more easily use dry cooling (and in the event of water shortages, an even greater share will be dry cooling) due to the reduced cooling needs of these plants.

- We use an estimate of the additional cost of dry cooling from calculations made by Powers Engineering (2006) for retrofitting generation in California. The company performed calculations for a hypothetical plant that find the increased cost of generation of converting from once-through cooling to a wet tower will be between \$0.0013/kilowatt hour (kWh) and \$0.0039/ kWh (against a wholesale price of \$0.07/kWh) depending on the capacity utilization of the plant. Powers Engineering also cites projections that dry-cooling retrofits would cost 25% more than wet-tower retrofits, which means that the range would be \$0.0016 to \$0.0049/kWh. These calculations assume a 7% interest rate and 100% debt financing. A more realistic mix with 55% debt financing, 45% equity financing (taxed at 50%), and property taxes triples the cost in the range of \$0.0048 to \$0.0147/kWh.

- Retrofits have the additional effect of making power production less efficient. Powers Engineering estimates that cooling will reduce the efficiency of the hypothetical plant and cost an additional 1–2% for retrofitting to wet closed-loop cooling. However, the company does not recommend a value for dry cooling, which is more energy intensive. A power consultant identifies increases of 1.9 % for production costs when retrofitting wet, closed-loop cooling and 4.9% for dry cooling (Maulbetsch 2006). Assuming that wholesale prices of \$0.07/kWh can be used as costs, multiplying those prices by 4.9% increases the cost by \$0.00343/kWh.

- The increased investments in equipment increases the total cost of retrofits in a range of \$0.00823 to \$0.01813/kWh. We assume that the high end of the range is correct and that retrofits to dry cooling will increase generation costs by an additional \$18.13/megawatt hour (MWh).We assume that the high end of the range is correct and that retrofits to dry cooling will increase generation costs by an additional $18.13/megawatt hour (MWh).

- An alternative backstop technology is gas turbines. The turbines tend to be relatively expensive to use because the price of natural gas is high, and the turbines have low utilization rates because they mainly are used to serve peak demand. For these reasons, we assume that power producers will not switch to gas turbines to mitigate water shortages.

- We assume that once retrofits have been implemented, the electric power in a state will be able to operate fully with the reduced level of water consumption at the increased costs in future years.

As different states have different mixes of once-through cooling, the states are affected differently by water shortages. For example, all cooling in many arid states is done by the wet, closed-loop type because such states lack the water volume required for once-through cooling.[24] However, we assume that water shortages will affect the power production of generation technologies that commonly consume water (i.e., fueled by coal, natural gas, nuclear, other, other biomass, other gases, petroleum, and wood and derived fuels) in proportion to the state's water shortage. This is a conservative estimate for four reasons. First, wet, closed-loop cooling consumes a much greater amount of water than does once-through cooling for the same power production. It is likely that wet, closed-loop cooling would be converted first to dry cooling. This conversion would reduce a large fraction of water consumption but affect relatively little power production. For example, we estimate that in Texas wet, closed-loop cooling consumes 97% of all water consumed for cooling but produces only 62% of power.[25] Our conservative assumption is that a 97% reduction in available water would require that 97% of the power-plant capacity be retrofitted to deal with that water shortage—likely an overestimate. Second, some portion of the power produced in each state, especially the power produced with natural gas, already uses dry cooling. Consequently, fewer power plants within each state would need to retrofit their cooling mechanisms. Third, retrofits would first occur for power plants that operate at a high-capacity utilization rate; thus the costs of a retrofit in reality should be lower for mild water shortages. Fourth, power plants that use ocean water as their source are unlikely to require retrofitting because they consume salt water from a source that is expected to increase in volume.

B.4.1.2 Modeling Procedures

The additional production cost of electric power in each state, *i*, and each year, *t*, is calculated from EIA (2009) as

$$\Delta Y_t^i = \$18.13 * (1 - E_t^i) * X^i,$$

where

[24] Calculated from EIA (no associated date) titled "Annual Steam-Electric Plant Operation and Design Data" using data from 2005.

[25] *Ibid.*

E_t^i = the fraction of normal demand for water by electric power producers that is satisfied and

X^i = the total power production, in MWh, of production in the state in 2007 for power fueled by coal, natural gas, nuclear, other, other biomass, other gases, petroleum, and wood and derived fuels.

Because producers can permanently operate with a reduced supply of water following retrofits, $E_{t+1}^i \le E_t^i$. In years where the electric power available for electricity production decreases (i.e., $E_t^i < E_{t-1}^i$), investment in cooling retrofits is measured by[26]

$$\Delta IN_t^i = \$71.35 * (E_{t-1}^i - E_t^i) * X^i,$$

which assumes that all investments are made immediately.

The REMI model contains a "Cap and Trade Scenario" testing capability that provides guidance in modeling the economic impacts of cap-and-trade policies. Because cap and trade is likely to impact the electric power generation sector, the REMI Cap and Trade analysis suggests manipulating utility costs. An increase in production costs due to retrofitting equipment to reduce water use, as used in our analysis, is a similar cost increase.

Utility costs are changed by increasing the production costs for the utilities sector. Specifically, we exogenously increase the value of the production costs in the utilities sector by the amount (ΔY_t^i) determined by the above equation. During years where producers must invest in retrofitting technologies, this additional demand (ΔIN_t^i from the above equation) is invested. We then exogenously modify the REMI model's investment spending for what REMI calls "Producer's Durable Equipment." This approach, however, allocates demand generically in a way that overly favors production in industries like computer and electronic product manufacturing. Thus, we use REMI's translator module to adjust these numbers for different types of equipment, such as industrial equipment. Like the translator for agriculture, the equipment translator produces many variables (up to 65) that are slightly different for each region. We estimate that around 60% of additional net demand goes to the machinery manufacturing sector and 33% goes to the electrical equipment and appliance manufacturing sector. To simplify the calculations, we assume that two-thirds of ΔIN_t^i goes to the machinery manufacturing sector and one-third goes to the electrical equipment and appliance manufacturing sector by modifying the REMI policy option for exogenous final demand.

[26] Calculations from Powers Engineering (2006) for a retrofit from once-through to wet-tower cooling are \$100,000/MW of capacity. Using their estimate that dry cooling costs 25% more, this value becomes \$125,000/MW. Using the low-end capacity of 20% (8,760 hours × 0.20 = 1,752 kWh per year), this averages to \$71.35/MWh.

B.4.2 Thermoelectric Power in States Adjacent to an Ocean

If there is a shortage of fresh water, power plants near the ocean can directly use saline water, can have the water shipped inland via a pipeline to the facility, or can convert (municipal) desalinated water for their own use.

B.4.2.1 Modeling Assumptions

In states that are adjacent to oceans, we assume that water shortages experienced by the electric power industry are mitigated by using once-through cooling with saline ocean water or by desalinating water and using it in wet-tower cooling. We assume that thermoelectric generation plants in a state will conserve water by switching wet-tower cooling systems to desalinated water during water shortages.

Because desalination is a proven technology, we assume that any state on a coast has access to desalinated water as a backstop before water shortages become too severe. (In addition, states not on the coast may have access to desalinated brackish water, but we ignore this possibility because it would affect a relatively small population.) In these states, the main consideration for modeling is the increased cost of the desalination process.

Desalinated saline water is more expensive than surface or ground water. A recent study cited the current price of water in San Diego as $0.24/m^3 but the cost of desalination as between $0.64 and $1.04/m^3 (NRC 2008). A review of cost estimates for various technologies conducted by Miller (2003) at Sandia found estimates from 23 studies. For sea water, these estimates ranged from $0.27 to $6.56/m^3; however, the high range is an outlier. Removing one study puts the upper estimate at $1.86/m^3. We assume that the upper estimate is correct and that using desalinated water will increase the cost by $1.62/m^3.

A study of water use by thermoelectric plants found that the mean withdrawals per kWh of electricity for evaporative cooling was between 4.54 and 4.95 cubic decimeters (dm^3) for one kWh, depending on the technology used (Yang and Dziegielewski 2007). Taking the larger value, we assume a value of 4.95m^3/MWh. Thus the additional cost of using desalinated water in wet-tower cooling is $9.21/MWh. Because the cost of using desalinated water is about half the cost of converting to dry cooling ($9.21/MWh versus $18.13/MWh), conservation of water will likely occur by substituting desalinated water.

B.4.2.2 Modeling Procedures

The additional production cost of electric power in each state, *i*, and each year, *t*, is calculated by

$$\Delta Y_t^i = \$9.21 * (1 - E_t^i) * X^i,$$

where

E_t^i = the fraction of normal demand for water by electric power producers that is satisfied, and

X^i = the total power production, in MWh, of production in the state in 2007 for power fueled by coal, natural gas, nuclear, other, other biomass, other gases, petroleum, and wood and derived fuels (EIA 2009).

In states where cooling retrofits are necessary to conserve water, electricity production could permanently operate with less water. However, in the case of states adjacent to oceans, electricity producers may use desalinated water in one year and return to fresh water in the following years if the shortages are less severe.

As discussed previously, we exogenously increase the value of the REMI "Production Cost" (amount)" variable for the utilities sector by the amount ΔY_t^i determined by the above equation. In addition, we exogenously increase the value of the "Industry Sales/Production" variable for the utilities industry by an amount equal to ΔY_t^i to account for the increased water production that the power generators require from water utilities that provide desalinated water. Increases in production in the REMI model automatically trigger investment in the industry; thus the REMI model automatically accounts for investments that are made to build desalination capacity.

B.4.3 Hydroelectric Power

Hydroelectric plants are fully dependent on water flow. The enduring loss of water requires the construction of new renewable-energy, fossil, or nuclear-powered facilities.

B.4.3.1 Modeling Assumptions

Drought conditions will change rainfall and thus change the volumes of water flowing through rivers and streams. Hydroelectric power creates electricity from the potential energy in water, so lesser or greater flows of water correspondingly reduce or increase the amount of power that can be generated by a hydroelectric plant.

We approximate the marginal cost of producing hydroelectric power as zero because the major costs of producing hydroelectric power are about the same regardless of how much power the plant actually produces. Capital costs to build hydroelectric power generation are sunk costs. Thus the cost of producing electricity is the same no matter how much power is produced. Labor costs are relatively small; the same amount of labor is required from workers, such as guards and operators, irrespective of the level of power production. Hydroelectric power does not use a costly fuel source as does thermoelectric power. Thus changes to hydroelectric power, alone, are not assumed to have any aggregate macroeconomic impact.

Changes to hydroelectric power production will have a macroeconomic impact through substitutions away from or to other forms of production with a greater marginal cost. We assume that reductions in hydroelectric power lead to an equally large increase in demand for thermoelectric power, whereas decreases in hydroelectric power lead to an equally large decrease in demand for thermoelectric power within the state where the hydroelectric power is produced. These changing demands change production levels but not necessarily within the same state—power can be imported or exported outside a region.

We assume a monetary value for changes in demand of $138.13/MWh, which is equal to the cost of new coal-power generation ($120/MWh)[27] plus the costs of retrofits to dry cooling towers ($18.13/MWh—a conservative assumption because cooling "retrofits" will likely be cheaper to implement when designed into new construction).

We do not calculate any changes to demand for other sectors. In reality, an increase in demand for the utilities sector, for example, could reduce demand for other sectors because of price and income effects. However, modeling at this detailed level is beyond the scope of this study. By assuming that there are no changes to demand in other sectors due to changes in demand for the utilities sector, we are setting the bounds of the maximum possible impact.

B.4.3.2 Modeling Procedures

Changes in the demand for alternate sources of power resulting from changes in hydroelectric production are treated in the REMI model as a change in the "Exogenous Final Demand (amount)" variable of the utilities sector. To satisfy changes in demand, the REMI model changes production and investment in capital stock (e.g., increasing capital stock if thermoelectric power plants are needed) in a state and its neighbors.

The change in the "Exogenous Final Demand (amount)" variable for the utilities sector in state i and year t is calculated as

$$\Delta D_t^i = \$138.13 * (HP_t^i - 1) * X_{HP}^i$$

where

HP_t^i = the fraction of normal hydroelectric power production in state i and year t and

X_{HP}^i = the total hydroelectric power production, in MWh, in the state in 2007 (EIA 2009).

B.5 Modeling Impacts to Industry and Mining

Of all the major sectors of water withdrawal for the United States, industry is the smallest (5% of all water withdrawals) after thermoelectric power (48%), irrigation of agriculture (34%), and public water supplies (11%) (Hutson et al. 2004). Mining, whose water availability is modeled separately from the aggregate of other industries, consumes less than 1% of all water.

[27] LAZARD (2008) and a transmission and distribution cost of $20/MWh (Northwest Power and Conservation Council [2009]).

B.5.1 Modeling Assumptions

A USGS report (Hutson et al. 2004) provides information about aggregate withdrawals of water for all industries and mining but does not break down the numbers by specific industry or provide data on how much water is consumed (e.g., evaporated or incorporated into a product) or returned to its source, such as with once-through cooling. Statistics Canada (2005a), on the other hand, provides a large number of tables with a large breadth of data based on surveys of industrial and mining users of water. We assume that the water use of Canadian industries mirrors that of U.S. industries, proportionally. This assumption is reasonable because the two countries use similar technologies, and the industries are both classified according to the North American Industry Classification System (NAICS). (Because temperatures in the United States are generally warmer than in Canada, it is possible that more U.S. industrial water is used for cooling. In the bullets below [beginning with "Food"], a greater amount of cooling means that there are more opportunities for cutting back the amount of water used by converting to dry cooling. Thus assuming that the United States and Canada use the same proportions for cooling is a conservative approach.)

Hutson et al. (2004) state that food, paper, chemicals, refined petroleum, and primary metals are the largest industrial users of water, and these researchers provide separate data for the mining industry. The Statistics Canada (2005a) survey reports similar findings but also includes the beverage and tobacco manufacturing sector as a significant consumer of water. These six industries account for 87% of all industrial (nonmining) consumption of water. We have focused on these industries.

The data from the hydrological model used in this study give the percentage of normal consumption that can be provided by water supplies. Therefore, we assume there is plenty of water to withdraw, but only a limited amount of this water can be consumed. The remainder of the water must be treated and returned to water supplies where it can be withdrawn and ultimately consumed by other users.

A summary of pertinent statistics for the Statistics Canada survey is provided in Table B-4. Only 13.5% of water intake is actually consumed. The remainder of the water is for the following:

- **Food.** Disclosure problems make it difficult to see clearly what is happening in the data. It is likely that a large portion of the food industry's water consumption is used for sanitary service, most likely in the animal-processing industries. This water is probably relatively difficult to conserve, but it can be treated or transferred to irrigation use. Surface discharge is very small, probably because it is difficult to treat. It is likely that most of the discharge becomes irrigation water. (The italicized values in Table B-4 indicate undisclosed data that we input by assuming that 29% of water intake is used for cooling, as it is in the beverage and tobacco industry.)

- **Beverage and Tobacco.** This industry's consumption rate is the highest of all at 51%. The high percentage is likely due to the fact that water composes the majority of most beverages.

- **Paper.** This industry's consumption rate is only 5%, and it discharges 89% of its intake to the surface, and it spends a lot of money doing these activities. There is very little this industry can do to conserve because it consumes so little and is already spending a lot to treat water.

- **Petroleum and Coal.** This industry is based on transforming petroleum and coal into usable products (i.e., the industry does not include extraction). The industry has a consumption rate of 12%. Much of this is likely due to evaporation, as 87% of the water is used for cooling, condensing, and steam. The 12% could be conserved using similar technologies to those identified for electricity generation.

- **Chemicals.** This industry consumes a relatively high amount of water, probably because the water is used in chemical reactions or as a solute. There is no conservation opportunity with this use of water. Because a large portion of water is used for cooling, condensing, and steam (80%), there are opportunities to conserve water here by using similar technologies to those identified for electricity generation.

- **Primary Metals.** Primary metals manufacturing uses a moderate amount of water in cooling, condensing, and steam (hence there are moderate conservation opportunities) and returns a relatively large percentage of water (80%) in surface discharge.

- **Mining.** Statistics Canada surveys only the mining (except oil and gas) sector. Surface discharge is 98% of withdrawals. Consumption is –37% because mining often "generates" water when mines are below the water table. If the intake is adjusted by adding mine water, the total intake is 674.9 million cubic meters (mil m^3) of water per year and 7% of that amount is consumption. The recycling rate is 448%, meaning that the same water is used over and over again. Since mining consumes so little water and already has a high recycling rate, there are few conservation opportunities.

The USGS study of water use in the United States, i.e., Hutson et al. (2004), includes oil and gas in its mining data. These data are much more limited than the Canadian data and cover only a subset of states. The data report that mining uses 2,250 thousand acre-feet per year of fresh water and 1,660 thousand acre-feet of saline water. Of the saline water, 1,260 thousand acre-feet per year is ground water.

Table B-4. Industrial Use of Water in Canada[28]

	Food	Beverage/ Tobacco	Paper	Petroleum and Coal	Chemicals	Primary Metals	Mining	Mining (adjusted)
Intake (mil m^3)	1366.8	160.6	2598.3	364.8	532.5	1606.2	458.9	674.9
Consumption (mil m3)	272.7	81.3	134.3	42.3	149.9	238.4	-171.7	44.3
Consumption Rate	20%	51%	5%	12%	28%	15%	-37%	7%
Process Water	869.4	-	1800.4	42.5	92	518.8	376.7	376.7
% Intake	64%	-	69%	12%	17%	32%	82%	56%
% Cons.	319%	-	1341%	100%	61%	218%	-219%	850%
Cooling, Condensing, Steam	*394.0*	46.3	731.9	317.5	423.4	839.6	37.7	37.7
% Intake	*29%*	29%	28%	87%	80%	52%	8%	6%
% Cons.	*144%*	57%	545%	751%	282%	352%	-22%	85%

[28] Data from Statistics Canada (2005a).

Information about the output of Canadian industries is included in Table B-5. We assume that U.S. industries use water at the same rate, per amount of output, as Canadian industries (i.e., the right column of Table B-5 is representative of U.S. industries). Due to a lack of information about water use in oil and gas extraction, we assume that the industry has the same water-use characteristics as the mining (except oil and gas) sector.

To calculate the costs of retrofitting cooling systems to dry-cooling systems, we assume that the costs per amount of water consumption saved are the same as in the electric power industry. We assume that the maximum percentage of water that can be conserved by retrofitting cooling systems in each industry is equal to the amount of water used in cooling divided by the total intake. This value ranges from 6% for mining to 87% for petrochemicals and coal. Again, we assume a value of the previously mentioned 4.95m^3/MWh for the amount of water used by thermoelectric plants for evaporative cooling (Yang and Dziegielewski 2007), and we use the previous value for retrofitting power generation plants of \$18.13/MWh. Dividing \$18.13/MWh by 4.95m^3/MWh equals an additional cost of \$3.66/m^3 for water saved by retrofitting to dry cooling.[29]

We use the previous value of investment necessary to retrofit power generation plants of \$71.35/MWh. Dividing this value by 4.95m^3/MWh equals an investment cost of \$14.41/m^3 for water conserved by retrofitting to dry cooling. As with electric power, any cooling retrofits that occur will reduce the industrial requirements for water in future years.

We assume that once the maximum amount of water has been conserved by retrofitting to dry cooling, additional water is not easily conserved because it often goes into production or is otherwise lost in the production process. Water must be obtained through desalination, or otherwise firms must shut down production to conserve any remaining water. Desalination is available to firms in states that are adjacent to an ocean at an increased cost of \$1.62/m^3 (for the reasons noted previously). Because the increased cost of using desalinated water is much cheaper than the increased cost of retrofitting to dry cooling, we assume that firms will use desalinated water to adjust to the shortfall in water. Firms in all industries conserve water in the same proportion (e.g., if the available water is a fraction I_t^i of normal demand, all firms have access to that fraction.)

In states not adjacent to an ocean, we assume that all industries initially retrofit cooling systems to conserve water. For simplification purposes, industries retrofit according to a linear function that is proportional to the industry's consumption of water for cooling purposes multiplied by the water shortfall.[30] Once all retrofits have been performed, if the retrofits have not conserved enough water, industries shut down in equal proportions. This is a conservative assumption because industries are likely to shut down according to how intensively they use water for noncooling purposes (based upon

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[29] This amount is slightly more expensive than the \$1.62/m^3 increase for desalinated water used previously. Thus, it may be slightly cheaper for a wet closed-loop cooling system to use desalinated water rather than to retrofit the system. However, the cooling in these data is an aggregate of both wet closed-loop and once-through types.

[30] The implication of this assumption is that different industries will conserve water at different rates depending upon the intensity at which the industries consume water for cooling.

water consumption per dollar of output), with the most intensive industries shutting down first. Calculations of these intensities are given in Table B-5.

Table B-5. Noncooling Consumption Rates Compared with Industry Output

	Noncooling Consumption (mil m^3)[31]	2005 Output $CAN mil (2002)[32]	Output in $US mil (2008)[33]	Noncooling Consumption m^3/$M US Output
Food Manufacturing	194.1	$71,028	$102,330	1,897
Beverage and Tobacco Product Manufacturing	57.9	$13,901	$20,027	2,889
Paper Manufacturing	96.5	$33,546	$48,330	1,996
Petroleum and Coal Product Manufacturing	5.5	$59,228	$85,330	64
Chemical Manufacturing	30.7	$54,659	$78,747	390
Primary Metal Manufacturing	113.8	$49,790	$71,733	1,586

Table B-6 provides the water use by industry based on Canadian statistics. Column one gives the percentage of water intake that is used for cooling, column two gives the total amount of water consumed by each industry in 2005 on an annual basis, and columns three and four list the value of economic output from each industry in Canadian and U.S. dollars, respectively. Column five lists the resulting consumption rate in terms of water volume per unit of economic activity.

[31] Statistics Canada (2005a).
[32] Statistics Canada (2005b).
[33] Converted to 2005 Canadian dollars by multiplying by 1.099 (112.27/102.13) (NationalMaster), converted to 2005 USD by multiplying by 1.21 (2005 exchange rate and PPP equivalence (International Comparison Project [2008]) and converted by 2008 USD by multiplying by 1.08 (122.422/113.026, EconStats).

Table B-6. Total Consumption[34]

	Cooling % Intake	Consumption (mil m^3)	2005 Output $CAN mil (2002)	Output in $US mil (2008)	Consumption m^3/$M US output
Food Manufacturing	29%	272.7	$71,028	$102,330	2,665
Beverage and Tobacco Product Manufacturing	29%	81.3	$13,901	$20,027	4,059
Paper Manufacturing	28%	134.3	$33,546	$48,330	2,779
Petroleum and Coal Product Manufacturing	87%	42.3	$59,228	$85,330	496
Chemical Manufacturing	80%	149.9	$54,659	$78,747	1,904
Primary Metal Manufacturing	52%	238.4	$49,790	$71,733	3,323
Mining (adjusted)	6%	44.3	$24,351	$35,083	1,263

B.5.2 Modeling Procedures

The following sections outline the equations used to determine the impacts from water shortages in industry, using the assumptions generated in Section B.5.1.

B.5.2.1 States not Adjacent to an Ocean

These states first retrofit industrial cooling systems to conserve water. If additional water conservation is necessary, industries must halt some production. For each state *i* and year *t*, a fraction of water consumption that can be saved through dry-cooling retrofits is calculated by weighting each industry's cooling-water intake as follows, using data from Table B-6, presented previously, and the REMI model's standard regional control outputs:

[34]Based on calculations in Tables B-4 and B-5.

$$\overline{\%c_t^i} = \frac{\%c_f WI_f Y_{f,t}^i + \%c_b WI_b Y_{b,t}^i + \%c_p WI_p Y_{p,t}^i + \%c_e WI_e Y_{e,t}^i + \%c_c WI_c Y_{c,t}^i + \%c_m WI_m Y_{m,t}^i}{WI_f Y_{f,t}^i + WI_b Y_{b,t}^i + WI_p Y_{p,t}^i + WI_e Y_{e,t}^i + WI_c Y_{c,t}^i + WI_m Y_{m,t}^i},$$

where

f, b, p, e, c, and m represent the six nonmining industries,

$\%c_x$ = the percentage of consumption assumed to be used in cooling,

WI_x = the water intensity of each industry, and

$Y_{x,t}^i$ = the output of industry x (in millions of 2008$ US, from the REMI model's standard regional control).

Because mining is disaggregated from data in the Sandia hydrological model, its value is simply 6%.

Production costs in each industry increase by[35]

$$\Delta PC_{x,t}^i = \begin{cases} (1-I_t^i)/\overline{\%c_t^i} * \$3.66 * \%c_x WI_x Y_{x,t}^i & \Big| (1-I_t^i) < \overline{\%c_t^i} \\ \$3.66 * \%c_x WI_x Y_{x,t}^i & \Big| (1-I_t^i) \geq \overline{\%c_t^i} \end{cases},$$

where

I_t^i = the fraction of usual water demanded that is available to all industries.

For mining, which includes both the mining (except oil and gas) sector and the oil and gas extraction sector, this equation simplifies to

$$\Delta PC_{m,t}^i = \begin{cases} (1-M_t^i)/0.06 * \$3.66 * 0.06 * 1263\, Y_{m,t}^i & \Big| (1-M_t^i) < 0.06 \\ \$3.66 * 0.06 * 1263\, Y_{m,t}^i & \Big| (1-M_t^i) \geq 0.06 \end{cases},$$

where

M_t^i = the fraction of usual water demanded that is available to mining.

Increases in production costs, $\Delta PC_{x,t}^i$, are inputs into the REMI model that exogenously increase the "Production Cost (amount)" variable for the appropriate

[35] The vertical line at the end of each equation given in this section notes the domain of the independent variable for which the equation is applicable.

industries. Investment in cooling-system retrofits are made until all industrial cooling systems have been retrofitted (i.e., $\overline{\%c_t}^i$ has been conserved. Investment is based upon previous retrofits in the following sets of equations:

$$\Delta IN^i_{x,t} = \begin{cases} (I^i_{t-1} - I^i_t) * \$14.41 * \%c_x WI_x Y^i_{x,t} & (1 - I^i_{t-1}) \le (1 - I^i_t) < \overline{\%c_t}^i \\ [I^i_{t-1} - (1 - \overline{\%c_t}^i)] * \$14.41 * \%c_x WI_x Y^i_{x,t} & (1 - I^i_{t-1}) < \overline{\%c_t}^i < (1 - I^i_t) \\ 0 & otherwise \end{cases}$$

and for mining:

$$\Delta IN^i_{m,t} = \begin{cases} (M^i_{t-1} - M^i_t) * \$14.41 * 0.06 * 1263 Y^i_{x,t} & (1 - M^i_{t-1}) \le (1 - M^i_t) < 0.06 \\ [M^i_{t-1} - (1 - 0.06)] * \$14.41 * 0.06 * 1263 Y^i_{x,t} & (1 - M^i_{t-1}) < 0.06 < (1 - M^i_t) \\ 0 & otherwise \end{cases}$$

The first case occurs when water availability is lower than the previous year but still higher than the maximum amount that can be conserved with cooling retrofits. The second case occurs when water availability is lower than the previous year and lower than the maximum that can be conserved with cooling system retrofits. The third case occurs when water availability increases or decreases further below the maximum retrofitting conservation amount. Because the industry can operate with less water every year to the point where all possible retrofits have been made,

$$I^i_t \le \max\left(I^i_{t-1}, (1 - \overline{\%c_t}^i)\right)$$

and

$$M^i_t \le \max\left(M^i_{t-1}, (1 - 0.06)\right)$$

As with investments for dry-cooling retrofits for electric power generation, we assume that two-thirds of $\Delta IN^i_{x,t}$ goes to the machinery manufacturing sector and one-third goes to the electrical equipment and appliance manufacturing sector by modifying the "Exogenous Final Demand (amount)" variable.

When water availability is below the level that can satisfy industry needs through cooling-system retrofits (e.g., $(1 - I^i_t) > \overline{\%c_t}^i$), firms must shut down some portion of production to conserve water. We assume that firms reduce their output in proportion to the amount that the water shortage exceeds the level that can be conserved with cooling system conservation. This can be represented as

$$\Delta Y^i_{x,t} = -(1 - I^i_t - \overline{\%c_t}^i)/(1 - \overline{\%c_t}^i) Y^i_{x,t} \Big| (1 - I^i_t) > \overline{\%c_t}^i.$$

For mining, the equation simplifies to

$$\Delta Y^i_{m,t} = -(1 - M^i_t - 0.06)/(1 - 0.06) Y^i_{m,t} \Big| (1 - M^i_t) > 0.06.$$

This change in industry output is treated in the REMI model as a change to the "Industry Behavior" component of the model through exogenously reducing "Industry Sales/Exogenous Production" in the model by an amount equaling $\Delta Y^i_{x,t}$. An alternative strategy is to adjust "Firm Sales" by changing "Firm Behavior," In the REMI model "Firm Behavior" is represented by a set of input adjustment parameters that allow "displacement [of production by local industries] due to competition in the local and nearby markets and the national market," whereas changes to what REMI calls "Industry Behavior" leads to an exogenous change in the production of local industries that will not be compensated for by other firms increasing their production levels. Although it is likely that firms in regions of the country with abundant water increase production to take up the slack created by water shortages, the REMI model does not include explicitly consider water availability. Because many of the firms picking up the slack in a REMI simulation would be within the same region, using "Firm Behavior" would result in unrealistically high levels of production as a result of water shortages. Thus, choosing "Industry Behavior" is the more suitable assumption.

B.5.2.2 States Adjacent to an Ocean

The hydrological model first attempts to purchase water rights to mitigate the impact or reduce regional water availability. Once this option is exhausted, these states conserve water by purchasing desalinated water with a cost of \$1.62/m^3 for water conserved. The increase in production costs for each industry is based upon the industry's water intensity for water consumption and the industry's output, as represented by $\Delta PC^i_{x,t} = \$1.62 * (1 - I^i_t) * WI_x Y^i_{x,t}$. This equation assumes that each industry loses the same fraction $(1 - I^i_t)$ of its normal water demanded. The whole amount of the change in production costs is applied as increased production costs for industry x, and a fraction of the amount, $\overline{\%c_t}^i$, is applied to increased production in the utility industry to correspond to increased production of desalinated water.

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Appendix C. Base-Case Normalization

Even in the absence of climate change, economic and population growth will lead to potential water shortages (EPA 2002; GAO 2003; Karl et al. 2009). The impacts from these water constraints are typically not considered within macroeconomic forecasts and are not included in the base-case REMI forecast used as the macroeconomic referent in the analysis presented in the body of this report.

The study uses the concept of water availability, which compares indicated demand with expected supply. If there is no change in usage behaviors, the macroeconomic referent would produce reduced water availability in the future. In reality, if there were constraints of water availability, industries and consumers would more efficiently use water to maintain operations. The analysis of the main text only includes differences in water availability beyond what are considered in the hydrological referent. We call this a normalization, where the implied (lack of) water availability in the referent is disregarded and only additional changes due to climate change are associated with macroeconomic impacts.

To present a more complete picture, this appendix presents the impacts of water constraints that are not due to climate change. The color-coded tables, organized by year and state, note the water availability for municipal utilities, industry, and thermoelectric facilities (Figure C-1) and for mining (Figure C-2). The estimated impacts that would occur for the GDP and for employment follow in Figure C-3, Figure C-4, and Table C-1. For all the tables and figures in this appendix, note that precipitation and thus hydrology is assumed constant over the entire time period. The change in water availability is solely due to the demand exceeding a constant supply.

In Figures C-1 and C-2 shown first, a water availability value of 1.0, depicted as green, indicates that all the water needed is available. As demand starts to exceed supply, a value less than 1.0 is present, and the color starts to turn yellow. When there is a significant gap between supply and demand, the numerical value diminishes further as yellow turns to red. Several states, including South Carolina, Tennessee, Virginia, and West Virginia, may experience rather severe water constraints even in the absence of climate change.

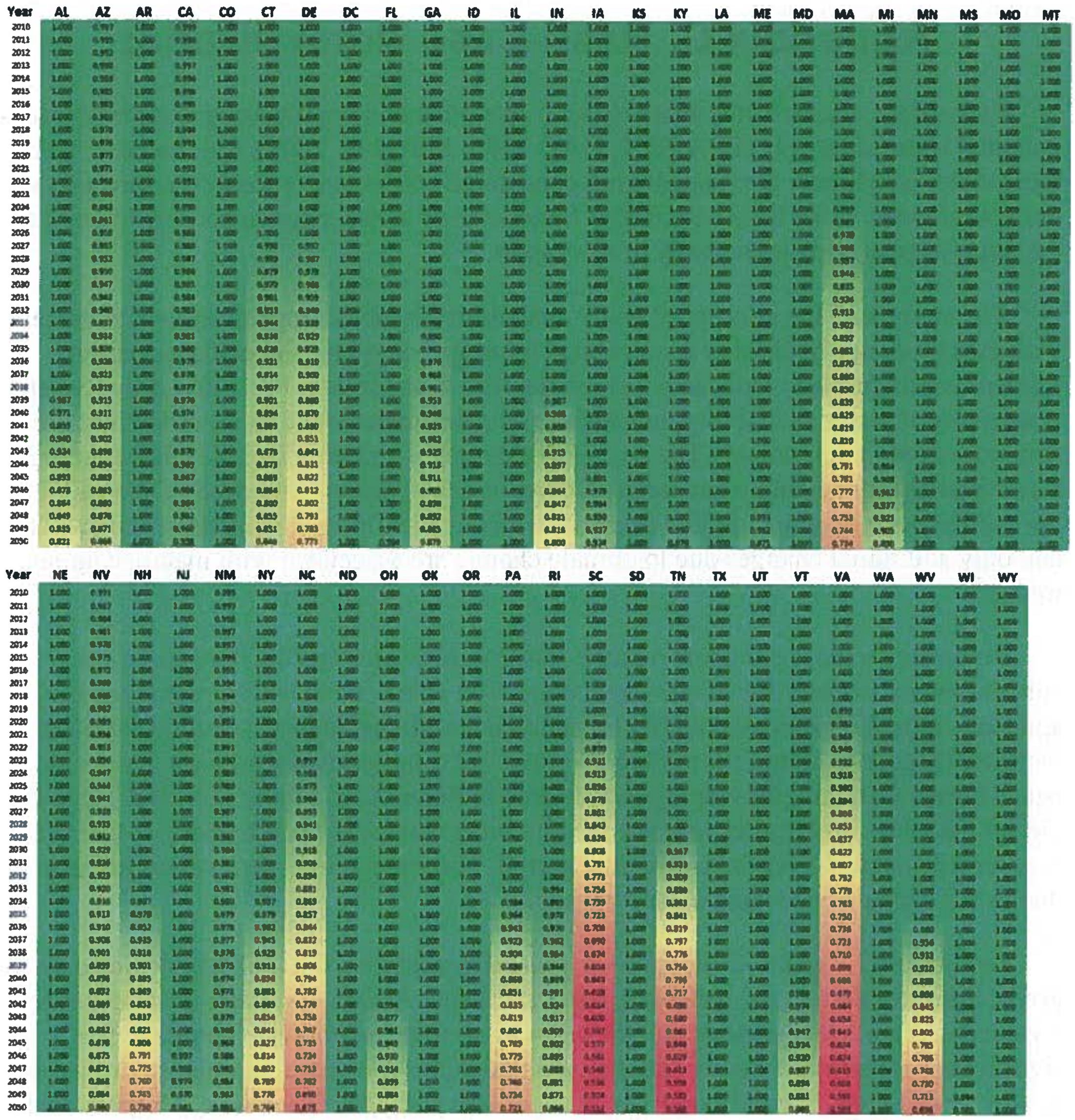

Figure C-1. Municipal, industry, and thermoelectric water availability in the hydrological referent.

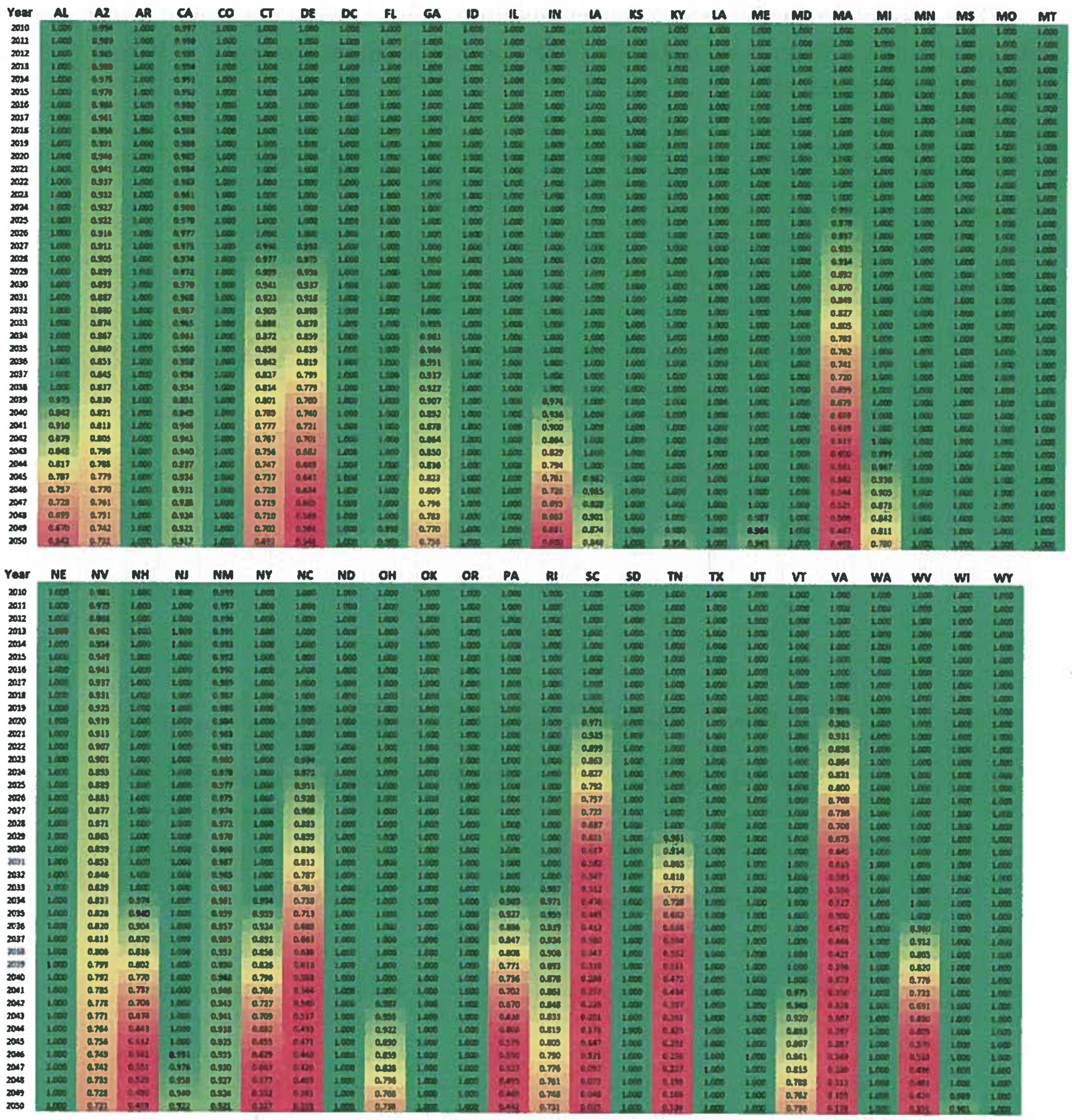

Figure C-2. Mining water availability in the hydrological referent.

The implied impacts of the water-availability constraints in the hydrological and macroeconomic referents on potential GDP and employment are noted in Figure C-3 and Figure C-4, respectively.

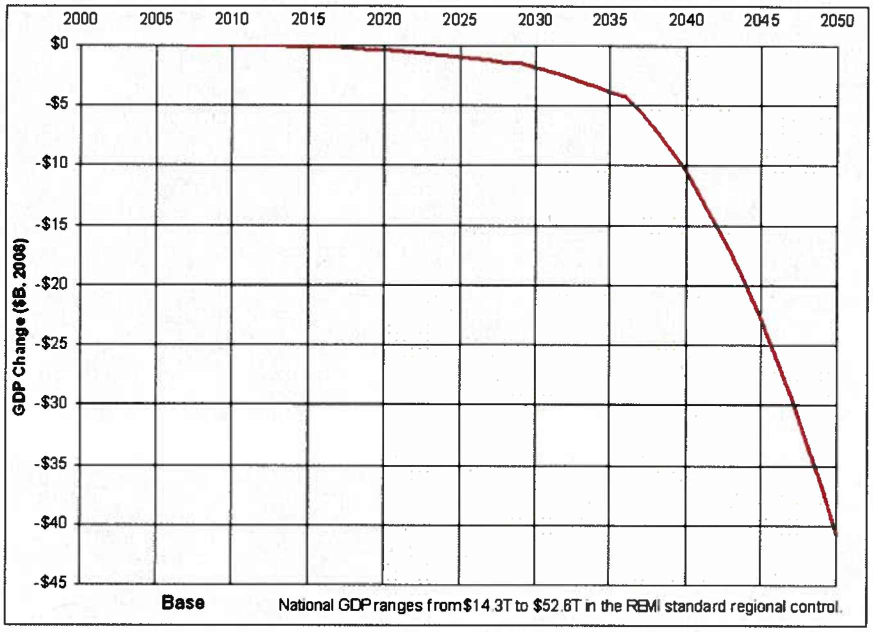

Figure C-3. National GDP impacts in the hydrological referent.

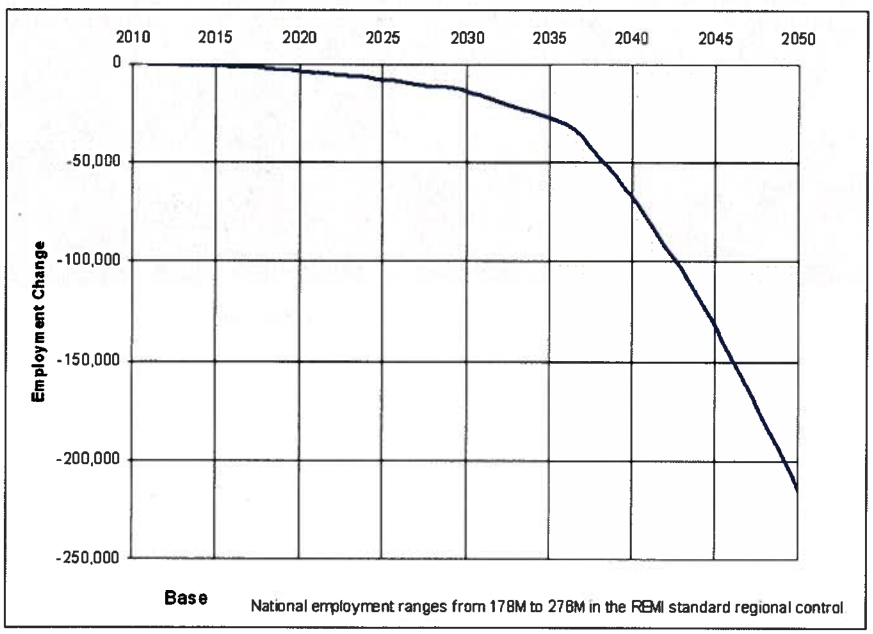

Figure C-4. National employment impacts in the hydrological referent.

Table C-1 provides a numerical listing of the implied impacts of water-availability constraints in the hydrological and macroeconomic referents. Note that the impacts are relatively small compared with the low-exceedance-probability climate impacts, such as in the $2 trillion in the 1% case. Nonetheless, the value of the implied impacts is nearly half the size of the 99% exceedance-probability results ($638 billion) in the body of the report, The national GDP loss due to predicted water constraints, even in the absence of climate change, is $316 billion (2008 $) at a 0% discount rate and $114 billion at a 3% discount rate. In other words, had the projected water shortages been included, the macroeconomic referent's forecast of the GDP (the starting point of the analysis) would have been $316 billion less at a 0% discount rate. Note again that none of these impacts are contained in the reported impacts of climate change. The climate-change impacts reflect only the difference between the referent and any simulation. See Section 3.2.4 for more information.

Table C-1. Base-Case Impacts

Base Case

Region	Change in GDP (0% D.R., $B)	Change in Empl. (1K Labor Yrs)	Change in Pop. (1K People)	Region	Change in GDP (0% D.R., $B)	Change in Empl. (1K Labor Yrs)	Change in Pop. (1K People)
United States	-$316.1	-1,873.6	0.0	Montana	-$0.6	-5.2	0.2
Alabama	-$1.5	-13.2	1.3	Nebraska	-$0.6	-3.8	1.0
Arizona	-$33.4	-207.5	-16.0	Nevada	-$24.4	-125.5	-8.1
Arkansas	-$0.7	-5.7	1.2	New Hampshire	-$0.5	-4.1	0.6
California	-$46.3	-251.3	8.3	New Jersey	-$5.7	-27.5	3.2
Colorado	-$2.5	-14.9	2.8	New Mexico	-$2.2	-17.2	-0.5
Connecticut	-$2.4	-11.2	1.4	New York	-$23.1	-78.4	6.5
Delaware	-$0.7	-3.7	0.2	North Carolina	-$5.3	-43.4	-1.1
District of Columbia	-$1.2	-4.6	0.2	North Dakota	-$0.4	-2.9	0.2
Florida	-$5.8	-40.1	9.4	Ohio	-$11.9	-75.9	-4.1
Georgia	-$3.9	-25.9	3.5	Oklahoma	-$1.3	-9.2	1.2
Idaho	-$0.5	-4.5	0.9	Oregon	-$0.9	-6.0	2.5
Illinois	-$5.0	-27.4	5.0	Pennsylvania	-$7.5	-56.9	0.2
Indiana	-$10.6	-64.3	-4.4	Rhode Island	-$0.4	-2.6	0.4
Iowa	-$1.1	-7.9	1.2	South Carolina	-$0.2	-14.9	-0.6
Kansas	-$0.9	-5.6	1.4	South Dakota	-$0.3	-2.2	0.4
Kentucky	-$3.8	-26.5	-1.2	Tennessee	-$19.7	-135.1	-7.6
Louisiana	-$2.4	-15.6	0.9	Texas	-$9.7	-55.4	11.2
Maine	-$0.4	-3.4	0.6	Utah	-$1.9	-14.1	1.0
Maryland	-$4.3	-26.0	0.8	Vermont	-$0.5	-4.0	0.1
Massachusetts	-$4.5	-23.7	2.6	Virginia	-$7.2	-50.0	-1.8
Michigan	-$6.2	-34.5	1.6	Washington	-$2.2	-11.0	3.7
Minnesota	-$1.9	-10.8	3.1	West Virginia	-$42.7	-258.4	-39.9
Mississippi	-$1.1	-8.6	0.5	Wisconsin	-$1.6	-10.5	2.7
Missouri	-$1.7	-11.2	2.9	Wyoming	-$1.1	-8.0	-0.5

Obs.: Changes in GDP and employment are summed over the 2010-2050 period, population is the 2050 value

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Appendix D. National and State Reference Values

(REMI Base-Case Control Run)

The analysis results presented in the body of this report are based on comparing macroeconomic values in the base-case forecast of the REMI model, the macroeconomic referent, with simulation values. Thus, the analysis results are the differences between the estimated values without climate change and the simulated values with climate change. In this appendix, we simply report the macroeconomic values from the base-case forecast so that one can compare the impacts (changes) noted in the analysis results on national- and state-level GDP, employment, personal income, and population. Table D-1 summarizes the national values of these variables for three sample years from the base-case forecast. Although data for all years during the period of the study are available, we have selected three representative years as illustrative of the economic trend.

Table D-1. National Summary Values

REMI Summary - National			
	2007	2025	2050
National GDP ($B)	$14,396.5	$23,304.3	$52,577.0
Employment (1K People)	181,668.7	201,023.2	275,903.9
Personal Income ($B)	$14,285.9	$38,129.8	$185,936.6
Population (1K People)	301,697.4	356,252.5	431,634.3

Table D-2, Table D-3, and Table D-4 provide values for state-level contribution to the GDP, employment, and population, respectively, for the three sample years. As an example, from Table D-3, West Virginia is forecast to have 1.249 million people employed in 2050 in the macroeconomic referent that does not consider future climate change.

Table D-2. GDP Values (2008$) in Base Case

REMI Summary - GDP

Region	GDP ($B)			Region	GDP ($B)		
	2007	2025	2050		2007	2025	2050
United States	$14,396.5	$23,304.3	$52,577.0	Montana	$33.0	$49.2	$113.0
Alabama	$171.4	$250.6	$575.3	Nebraska	$75.1	$111.7	$246.5
Arizona	$267.5	$473.2	$1,284.1	Nevada	$133.5	$212.6	$497.2
Arkansas	$93.1	$137.6	$312.4	New Hampshire	$64.0	$113.0	$273.3
California	$1,946.8	$3,551.8	$9,567.8	New Jersey	$505.9	$843.0	$1,733.8
Colorado	$261.0	$434.6	$922.2	New Mexico	$67.0	$99.8	$220.0
Connecticut	$217.6	$383.0	$819.8	New York	$1,199.0	$2,337.3	$5,339.2
Delaware	$49.0	$77.1	$161.2	North Carolina	$375.7	$569.8	$1,237.7
District of Columbia	$105.9	$153.0	$266.9	North Dakota	$26.2	$38.9	$91.4
Florida	$807.2	$1,256.1	$2,752.7	Ohio	$491.1	$702.3	$1,473.6
Georgia	$430.6	$676.5	$1,437.7	Oklahoma	$131.7	$184.3	$358.6
Idaho	$52.6	$86.2	$217.3	Oregon	$162.5	$274.1	$679.1
Illinois	$671.8	$998.5	$1,896.7	Pennsylvania	$559.1	$849.3	$1,760.7
Indiana	$260.6	$377.4	$844.6	Rhode Island	$46.7	$75.3	$163.6
Iowa	$120.5	$179.7	$414.1	South Carolina	$162.6	$239.2	$534.5
Kansas	$119.2	$180.4	$399.4	South Dakota	$28.4	$42.5	$101.3
Kentucky	$155.0	$224.3	$497.5	Tennessee	$252.2	$383.2	$884.4
Louisiana	$166.2	$236.3	$505.0	Texas	$1,107.9	$1,716.0	$3,599.9
Maine	$48.0	$74.4	$177.5	Utah	$104.5	$172.6	$428.4
Maryland	$295.2	$449.5	$885.9	Vermont	$25.2	$42.0	$102.2
Massachusetts	$407.0	$739.2	$1,706.4	Virginia	$408.5	$609.3	$1,168.5
Michigan	$427.9	$611.4	$1,366.4	Washington	$325.7	$539.8	$1,249.5
Minnesota	$279.4	$446.0	$954.2	West Virginia	$56.7	$81.1	$174.9
Mississippi	$85.0	$124.3	$299.6	Wisconsin	$243.1	$352.5	$760.8
Missouri	$247.4	$365.5	$764.9	Wyoming	$24.5	$33.4	$66.0

Table D-3. Employment Values in Base Case

REMI Summary - Employment

Region	Employment (1K People)		
	2007	2025	2050
United States	**181,668.7**	**201,023.2**	**275,903.9**
Alabama	2,629.7	2,667.1	3,633.6
Arizona	3,427.1	4,277.7	7,142.0
Arkansas	1,629.6	1,656.0	2,206.3
California	20,858.1	25,805.3	42,573.6
Colorado	3,241.5	3,797.3	5,001.3
Connecticut	2,291.6	2,716.3	3,598.3
Delaware	554.0	620.3	817.5
District of Columbia	819.5	897.2	1,095.0
Florida	10,781.8	12,110.2	16,457.8
Georgia	5,499.9	6,081.5	7,886.2
Idaho	919.1	1,035.8	1,554.2
Illinois	7,744.8	8,043.8	9,579.3
Indiana	3,785.0	3,706.4	4,816.5
Iowa	2,053.0	2,072.1	2,757.7
Kansas	1,876.0	1,911.6	2,424.0
Kentucky	2,462.9	2,427.0	3,131.0
Louisiana	2,510.1	2,505.0	3,224.4
Maine	857.1	932.0	1,324.4
Maryland	3,460.6	3,808.8	4,834.7
Massachusetts	4,299.5	5,276.1	7,712.2
Michigan	5,596.7	5,500.6	7,221.2
Minnesota	3,620.7	3,956.9	5,269.7
Mississippi	1,555.6	1,561.5	2,135.7
Missouri	3,739.4	3,830.2	4,798.1

Region	Employment (1K People)		
	2007	2025	2050
Montana	648.2	691.3	946.3
Nebraska	1,260.0	1,293.1	1,688.0
Nevada	1,653.3	1,995.6	3,041.7
New Hampshire	872.4	1,032.7	1,518.1
New Jersey	5,250.7	6,044.3	7,817.8
New Mexico	1,118.7	1,199.4	1,639.6
New York	11,279.2	14,183.8	19,805.2
North Carolina	5,401.3	5,723.9	7,632.1
North Dakota	492.6	506.1	691.2
Ohio	6,991.9	6,940.1	8,721.5
Oklahoma	2,184.1	2,164.7	2,550.3
Oregon	2,327.4	2,681.6	4,031.8
Pennsylvania	7,430.0	7,971.3	10,368.3
Rhode Island	631.3	706.8	962.1
South Carolina	2,484.8	2,590.7	3,446.4
South Dakota	564.3	577.7	792.8
Tennessee	3,795.7	3,995.6	5,442.4
Texas	13,795.8	15,031.5	19,580.4
Utah	1,626.4	1,877.9	2,807.3
Vermont	437.9	498.9	732.3
Virginia	4,929.5	5,246.5	6,390.4
Washington	3,947.0	4,469.7	5,985.1
West Virginia	941.2	952.4	1,249.6
Wisconsin	3,658.2	3,640.9	4,615.5
Wyoming	384.5	387.3	482.2

Table D-4. Population Values in Base Case

REMI Summary - Population

Region	Population (1K People)			Region	Population (1K People)		
	2007	2025	2050		2007	2025	2050
United States	**301,697.4**	**356,252.5**	**431,634.3**	Montana	960.7	1,157.0	1,370.1
Alabama	4,655.9	5,376.4	6,505.1	Nebraska	1,777.1	1,981.7	2,341.0
Arizona	6,333.5	9,072.9	13,178.3	Nevada	2,595.4	3,957.9	5,565.1
Arkansas	2,834.0	3,165.3	3,764.4	New Hampshire	1,323.3	1,622.9	2,045.4
California	36,461.9	44,179.3	60,212.1	New Jersey	8,707.4	10,249.0	12,081.6
Colorado	4,845.4	6,254.8	7,673.4	New Mexico	1,968.9	2,352.0	2,786.1
Connecticut	3,505.1	4,151.4	4,867.2	New York	19,320.2	23,622.1	28,435.4
Delaware	867.6	1,087.9	1,304.0	North Carolina	9,026.8	11,067.5	13,746.4
District of Columbia	586.0	687.6	760.6	North Dakota	640.4	717.9	858.0
Florida	18,435.3	23,667.8	29,182.5	Ohio	11,471.8	11,721.0	12,811.1
Georgia	9,564.5	12,310.0	15,097.4	Oklahoma	3,627.4	4,179.0	4,411.2
Idaho	1,496.5	1,927.7	2,486.3	Oregon	3,732.4	4,556.1	5,809.2
Illinois	12,832.5	13,865.1	15,120.9	Pennsylvania	12,428.5	13,796.8	15,955.4
Indiana	6,348.2	6,697.8	7,634.3	Rhode Island	1,056.7	1,162.6	1,420.4
Iowa	2,982.7	3,189.2	3,772.4	South Carolina	4,401.5	5,243.1	6,296.5
Kansas	2,776.8	3,102.9	3,568.2	South Dakota	796.4	902.1	1,095.7
Kentucky	4,233.5	4,589.4	5,264.9	Tennessee	6,180.9	7,382.6	9,152.0
Louisiana	4,239.9	4,320.0	4,670.8	Texas	23,934.4	30,166.7	35,335.9
Maine	1,318.9	1,497.3	1,859.6	Utah	2,638.1	3,438.7	4,519.9
Maryland	5,627.7	6,422.6	7,321.0	Vermont	621.7	721.2	908.2
Massachusetts	6,443.3	7,636.5	9,593.5	Virginia	7,669.6	8,806.8	9,941.3
Michigan	10,081.8	10,003.8	11,250.9	Washington	6,438.9	7,706.5	9,256.7
Minnesota	5,179.7	5,872.0	6,931.8	West Virginia	1,815.9	1,988.8	2,270.4
Mississippi	2,928.2	3,259.5	3,853.8	Wisconsin	5,599.6	5,942.5	6,717.4
Missouri	5,892.3	6,571.2	7,363.0	Wyoming	521.9	627.4	696.2

Table D-5 lists the sums of GDP and employment from 2010 to 2050 for comparison with summary-risk values presented in the body of the report. Note that the population column in Table D-5 reflects only the number of people in 2050 and thus does not contain summed values. As an example from Table D-5, from 2010 to 2050 West Virginia is forecast to produce a GDP of $4,139 billion with approximately 42,000 labor years of work. In 2050, the population of West Virginia is estimated to be 2,270,400. Note that the values in all tables in this appendix are raw numbers; no discount rate has been applied to any monetary quantity.

Table D-5. REMI Control Totals from 2010 to 2050 for Comparison with Summary-Risk Values

REMI Control

Region	Actual GDP (0% D.R., $B)	Total Empl. (1K Labor Yrs)	Total Pop. (1K People)	Region	Actual GDP (0% D.R., $B)	Total Empl. (1K Labor Yrs)	Total Pop. (1K People)
United States	$1,205,010.9	8,904,915.3	431,634.3	Montana	2,539.9	30,394.7	1,370.1
Alabama	13,060.5	118,619.9	6,505.1	Nebraska	$5,729.1	56,687.1	2,341.0
Arizona	26,227.5	200,555.2	13,178.3	Nevada	$11,162.4	91,094.1	5,565.1
Arkansas	7,135.0	73,129.3	3,764.4	New Hampshire	$5,968.5	46,500.4	2,045.4
California	194,884.5	1,198,924.8	60,212.1	New Jersey	$42,181.7	263,489.3	12,081.6
Colorado	21,930.5	165,784.1	7,673.4	New Mexico	$5,092.0	53,022.3	2,786.1
Connecticut	19,398.5	118,904.9	4,887.2	New York	$121,460.4	629,356.1	28,435.4
Delaware	3,886.2	27,241.3	1,304.0	North Carolina	$29,140.7	252,978.9	13,746.4
District of Columbia	7,272.2	38,755.3	760.6	North Dakota	$2,030.8	22,345.7	858.0
Florida	64,499.4	536,695.5	29,182.5	Ohio	$35,371.5	301,487.9	12,811.1
Georgia	34,271.8	265,741.3	15,097.4	Oklahoma	$8,950.0	91,851.1	4,411.2
Idaho	4,611.7	46,843.1	2,486.3	Oregon	$14,566.7	121,380.6	5,809.2
Illinois	48,640.4	344,045.3	15,120.9	Pennsylvania	$42,663.9	349,127.0	15,955.4
Indiana	19,473.5	162,758.6	7,634.3	Rhode Island	$3,838.8	31,282.5	1,420.4
Iowa	9,381.4	91,479.9	3,772.4	South Carolina	$12,348.1	114,323.0	6,296.5
Kansas	9,252.4	83,063.4	3,568.2	South Dakota	$2,236.8	25,611.3	1,095.7
Kentucky	11,542.1	106,435.9	5,264.9	Tennessee	$20,007.5	177,343.7	9,152.0
Louisiana	11,936.5	109,264.6	4,670.8	Texas	$85,902.3	654,617.7	35,335.9
Maine	3,926.9	41,776.4	1,859.6	Utah	$9,189.2	84,752.5	4,519.9
Maryland	22,244.7	165,901.4	7,321.0	Vermont	$2,228.0	22,514.4	908.2
Massachusetts	38,408.6	237,246.6	9,593.5	Virginia	$29,819.8	225,968.7	9,941.3
Michigan	31,493.7	241,971.3	11,250.9	Washington	$28,088.4	196,111.5	9,256.7
Minnesota	22,553.5	173,726.5	6,931.8	West Virginia	$4,139.0	41,932.1	2,270.4
Mississippi	6,587.4	69,447.8	3,853.8	Wisconsin	$17,941.5	158,508.4	6,717.4
Missouri	18,401.9	166,139.1	7,363.0	Wyoming	$1,632.1	16,624.6	696.2

Obs : GDP and employment are summed over the 2010-2050 period, population is the 2050 value

Appendix E. 1% Exceedance-Probability Impacts

National and State

This appendix provides detailed national and state information at the 1% exceedance probability. Our interest in this study has been to address the full range of possibilities of climate change, including the impacts of events that have a low probability and also a high consequence. The analysis results at the 1% exceedance probability in this appendix represent the worst-case example in our study and provide a more in-depth look at the impacts and their volatility by state and industry over time. The analysis results are the differences between the values forecast without climate change (from the macroeconomic referent discussed in Appendices C and D) and the simulated values with climate change. Note that the analysis results are based on a single motif as discussed in the main text. Thus, the results presented for any particular year are realizable for that time period but should not be considered a point prediction (see the discussion of motif in Section 3.1).

Note that some states experience a change in the sign of the impacts (from positive to negative or vice versa) or a reversal in the magnitude of the impacts. For example, a state may initially be positively affected because it has adequate water, but reduced precipitation in later years finally has an overall negative impact on the state. Conversely, a state may initially be negatively affected because of reduced precipitation, but the state may be positively affected (e.g., losses are reduced) in later years because the states surrounding it suffer more.

Table E-1 shows the GDP impacts for industry at the national level by decade. The values in this table and other "by decade" tables in this appendix are not cumulative over the particular decades. Thus, the values listed in Table E-1 for, say, 2050, for all industries listed represent only the GDP impacts for 2050, not a summation of such impacts from 2040 to 2050. Taking the ambulatory health care services industry as an example, we note that in 2050 this industry is estimated to experience a loss of $11.3 billion at the 1% exceedance probability. This loss is due to reduced labor earnings reducing the demand for health care along with the demand for other goods and services.

Table E-2 provides the contribution of individual states to the GDP by decade at the 1% exceedance probability. The entry for the United States (entire nation) in the table includes the impacts on Alaska and Hawaii, which are not listed in the table. Each succeeding decadal value for the United States (on the first row) is reflective of the overall downward trend. Most states at these 10-year marks are also illustrative of this trend, though there is some volatility in loss in a few of the states, like California, and no loss in some states such as Idaho, Oregon, and Washington.

Table E-3 and Table E-4 illustrate the yearly changes in the contributions to the GDP by individual states. These tables highlight the volatility as well as the potential change in the sign of impacts for some states. Taking New Mexico as an example, we observe the volatility at the 1% exceedance probability beginning in 2012, where the loss goes back and forth from $0.2 to $0.1 billion until 2015 when the loss jumps by a factor of 10 to

$1.2 billion. Similar volatility is present to 2050, reflective of the overall downward trend in the state's contribution to the GDP. In 2050, the impact reaches $2.9 billion, which is the greatest loss for New Mexico in the whole 40-year period.

Table E-5 shows the employment impacts per state by decade. As an example, the impact of climate change on West Virginia is a loss of 54,200 jobs in 2050 at the 1% exceedance probability. To determine the difference between this value and the employment value estimated in the base-case referent (in Appendix D, Table D-2), we subtract 54,200 from 1,249,000. This difference, 1,194,800, reflects the adjustment to the base case for 2050 as a result of climate change. In effect, the employment in West Virginia grows, but it grows more slowly with climate change.

Finally, Table E-6 through Table E-24 display the impacts for each state by industry-group with decadal resolution at the 1% exceedance probability. The values listed in each of these tables represent a particular industry's contribution (i.e., value-added output) to the GDP. To explain the contents of this data set, we look at Table E-10, which gives the contribution to the GDP by the educational services industry in 2020, 2030, 2040, and 2050. In 2050, Connecticut, Colorado, New Mexico, West Virginia, and Wisconsin all show a loss of $4.9 million as a result of climate change at the 1% exceedance probability. On the other hand, the educational services industry in 2050 does show positive impacts for some states. For example, from a loss in 2040 of $6.1 billion, this industry shows a gain of $11 million in 2050 in this worst-case example. Part of the explanation could be that people from other states that suffer as a result of climate change will have moved to California and led to growth in the educational services industry.

Table E-1. Change in GDP Contribution by Industry (1% Case)

Change in Contribution to GDP ($B) - 1% Case

Category	2010	2020	2030	2040	2050
Forestry and logging, Fishing, hunting, and trapping	-$0.001	-$0.016	-$0.023	-$0.017	-$0.005
Agriculture and forestry support activities, Other	$0.000	-$0.005	-$0.009	-$0.013	-$0.021
Oil and gas extraction	$0.028	-$0.021	-$1.578	-$0.393	-$0.968
Mining (except oil and gas)	$0.000	-$0.060	-$3.233	-$10.390	-$17.324
Support activities for mining	$0.000	-$0.047	-$0.295	-$0.703	-$1.483
Utilities	$0.425	$0.129	$0.873	$1.557	$0.274
Construction	-$0.023	-$0.695	-$1.583	-$1.658	-$2.197
Wood product manufacturing	$0.000	-$0.022	-$0.061	-$0.073	-$0.077
Nonmetallic mineral product manufacturing	$0.001	-$0.038	-$0.142	-$0.251	-$0.430
Primary metal manufacturing	$0.007	-$0.021	-$0.109	-$0.256	-$0.455
Fabricated metal product manufacturing	$0.007	-$0.070	-$0.197	-$0.267	-$0.297
Machinery manufacturing	$0.083	-$0.033	-$0.169	-$0.894	-$2.126
Computer and electronic product manufacturing	$0.001	-$0.094	-$0.371	-$0.765	-$1.640
Electrical equipment and appliance manufacturing	$0.038	-$0.010	$0.029	$0.028	$0.029
Motor vehicles, bodies & trailers, and parts manufacturing	$0.001	-$0.071	-$0.338	-$0.748	-$1.334
Other transportation equipment manufacturing	$0.000	-$0.004	-$0.054	-$0.138	-$0.262
Furniture and related product manufacturing	$0.000	-$0.032	-$0.125	-$0.273	-$0.555
Miscellaneous manufacturing	$0.000	$0.029	$0.022	$0.092	$0.289
Food manufacturing	-$0.045	-$0.847	-$2.020	-$4.001	-$7.082
Beverage and tobacco product manufacturing	-$0.022	-$0.371	-$0.817	-$1.438	-$2.184
Textile mills	$0.000	$0.001	$0.000	$0.001	$0.001
Textile product mills	$0.000	-$0.005	-$0.027	-$0.075	-$0.200
Apparel manufacturing	$0.000	$0.017	$0.028	$0.056	$0.111
Leather and allied product manufacturing	-$0.001	-$0.026	-$0.064	-$0.109	-$0.142
Paper manufacturing	-$0.001	-$0.038	-$0.114	-$0.198	-$0.321
Printing and related support activities	$0.000	-$0.012	-$0.033	-$0.042	-$0.043
Petroleum and coal product manufacturing	$0.002	-$0.015	-$0.149	-$0.370	-$0.650
Chemical manufacturing	-$0.001	-$0.154	-$0.662	-$1.509	-$2.981
Plastics and rubber product manufacturing	$0.000	-$0.065	-$0.212	-$0.340	-$0.437
Wholesale trade	-$0.015	-$0.703	-$1.891	-$3.035	-$4.424
Retail trade	-$0.071	-$1.223	-$3.875	-$8.746	-$17.328
Air transportation	$0.000	-$0.053	-$0.190	-$0.324	-$0.437
Rail transportation	$0.004	-$0.021	-$0.118	-$0.310	-$0.535

Category	2010	2020	2030	2040	2050
Water transportation	$0.000	$0.001	$0.000	$0.000	$0.000
Truck transportation, Couriers and messengers	-$0.001	-$0.195	-$0.764	-$1.610	-$2.647
Transit and ground passenger transportation	$0.001	-$0.004	-$0.029	-$0.056	-$0.084
Pipeline transportation	$0.007	-$0.001	-$0.011	-$0.018	-$0.036
Scenic and sightseeing transportation, support activities	$0.000	-$0.010	-$0.038	-$0.061	-$0.080
Warehousing and storage	$0.000	-$0.033	-$0.102	-$0.159	-$0.189
Publishing industries, except Internet	$0.000	-$0.136	-$0.466	-$0.950	-$1.820
Motion picture and sound recording industries	$0.000	-$0.036	-$0.138	-$0.343	-$0.763
Internet publishing and broadcasting, ISPs, search portals, and data processing; Other information services	$0.001	-$0.114	-$0.448	-$0.864	-$1.397
Broadcasting, except Internet, Telecommunications	$0.004	-$0.263	-$1.094	-$2.251	-$3.979
Monetary authorities - central bank; Credit intermediation and related activities; Funds, trusts, & other financial vehicles	$0.005	-$0.402	-$1.448	-$2.644	-$4.150
Securities, commodity contracts, investments	$0.002	-$0.426	-$1.737	-$3.348	-$5.065
Insurance carriers and related activities	$0.006	-$0.058	-$0.311	-$0.569	-$0.852
Real estate	$0.013	-$0.433	-$1.806	-$3.313	-$5.374
Rental and leasing services, Lessors of nonfinancial intangible assets	$0.006	-$0.100	-$0.700	-$0.579	-$0.671
Professional and technical services	$0.018	-$0.580	-$2.064	-$3.193	-$4.421
Management of companies and enterprises	-$0.005	-$0.233	-$0.742	-$1.036	-$1.053
Administrative and support services	$0.007	-$0.240	-$0.962	-$1.689	-$2.594
Waste management and remediation services	$0.001	-$0.010	-$0.042	-$0.045	-$0.044
Educational services	$0.001	-$0.016	-$0.095	-$0.200	-$0.343
Ambulatory health care services	$0.001	-$0.484	-$2.205	-$5.377	-$11.334
Hospitals	$0.005	-$0.027	-$0.208	-$0.491	-$0.993
Nursing and residential care facilities	$0.000	-$0.013	-$0.071	-$0.158	-$0.329
Social assistance	$0.001	-$0.009	-$0.067	-$0.166	-$0.371
Performing arts and spectator sports	$0.000	-$0.027	-$0.088	-$0.153	-$0.219
Museums, historical sites, zoos, and parks	$0.000	-$0.001	-$0.006	-$0.015	-$0.029
Amusement, gambling, and recreation	-$0.001	-$0.044	-$0.212	-$0.528	-$0.988
Accommodation	-$0.002	-$0.049	-$0.154	-$0.286	-$0.436
Food services and drinking places	-$0.040	-$0.338	-$0.649	-$1.022	-$1.323
Repair and maintenance	$0.001	-$0.053	-$0.209	-$0.394	-$0.633
Personal and laundry services	-$0.001	-$0.094	-$0.377	-$0.864	-$1.729
Membership associations and organizations	$0.001	-$0.016	-$0.081	-$0.163	-$0.284
Private households	$0.000	-$0.012	-$0.044	-$0.078	-$0.122

Table E-2. Change in GDP Contribution by State (1% Case)

Change in GDP ($B) - 1% Case

Region	2010	2020	2030	2040	2050
United States	**$0.5**	**-$10.2**	**-$38.4**	**-$74.3**	**-$130.0**
Alabama	$0.0	-$0.2	-$0.6	-$0.9	-$2.2
Arizona	$0.2	-$0.5	-$2.5	-$5.2	-$5.8
Arkansas	$0.0	-$0.1	-$0.3	-$0.5	-$1.2
California	$0.3	-$0.4	-$2.2	-$5.1	-$2.5
Colorado	$0.0	-$0.1	-$1.6	-$1.5	-$2.4
Connecticut	$0.0	-$0.1	-$0.3	-$0.5	-$0.9
Delaware	$0.0	$0.0	-$0.1	-$0.2	-$0.3
D.C.	$0.0	$0.0	-$0.1	-$0.3	-$0.5
Florida	-$0.1	-$1.6	-$3.0	-$4.8	-$7.8
Georgia	$0.0	-$1.0	-$2.0	-$3.3	-$6.2
Idaho	$0.0	$0.0	$0.0	$0.1	$0.1
Illinois	$0.0	$0.1	$0.0	-$1.3	-$5.2
Indiana	$0.0	$0.0	-$0.5	-$2.0	-$4.7
Iowa	$0.0	$0.0	$0.0	-$0.4	-$1.1
Kansas	$0.0	-$0.1	-$0.3	-$0.4	-$1.0
Kentucky	$0.0	-$0.2	-$0.5	-$2.9	-$6.8
Louisiana	$0.0	-$0.1	-$0.4	-$0.6	-$1.3
Maine	$0.0	$0.0	$0.0	$0.0	-$0.1
Maryland	$0.0	-$0.2	-$0.6	-$1.0	-$1.9
Massachusetts	$0.0	$0.0	-$0.3	-$0.5	-$1.1
Michigan	$0.0	-$0.1	-$0.3	-$1.5	-$3.3
Minnesota	$0.0	$0.0	-$0.1	-$0.7	-$2.0
Mississippi	$0.0	$0.0	-$0.1	-$0.3	-$0.7
Missouri	$0.0	$0.0	-$0.1	-$0.5	-$1.7
Montana	$0.0	$0.0	$0.0	-$0.1	-$0.1
Nebraska	$0.0	$0.0	-$0.1	-$0.3	-$0.6
Nevada	$0.0	-$0.1	-$1.0	-$3.6	-$2.4
New Hampshire	$0.0	$0.0	$0.0	-$0.1	-$0.2
New Jersey	$0.0	-$0.3	-$1.0	-$1.6	-$2.9
New Mexico	$0.0	-$0.2	-$1.6	-$1.7	-$2.4
New York	-$0.1	-$1.0	-$3.1	-$6.0	-$10.4
North Carolina	$0.0	-$0.6	-$1.2	-$2.2	-$4.2
North Dakota	$0.0	$0.0	$0.0	-$0.1	-$0.2
Ohio	$0.0	$0.0	-$1.1	-$2.9	-$5.8
Oklahoma	$0.0	-$0.4	-$2.9	-$1.5	-$3.6
Oregon	$0.0	$0.2	$0.2	$0.6	$1.1
Pennsylvania	$0.0	-$0.6	-$1.4	-$2.5	-$4.8
Rhode Island	$0.0	$0.0	$0.0	$0.0	-$0.1
South Carolina	$0.0	-$0.2	-$0.5	-$0.8	-$1.6
South Dakota	$0.0	$0.0	$0.0	-$0.1	-$0.2
Tennessee	$0.0	-$0.4	-$1.2	-$2.9	-$5.3
Texas	$0.0	-$1.3	-$3.6	-$5.4	-$9.8
Utah	$0.0	-$0.1	-$0.6	-$1.7	-$1.8
Vermont	$0.0	$0.0	$0.0	-$0.1	-$0.2
Virginia	$0.0	-$0.4	-$1.1	-$1.9	-$3.6
Washington	$0.0	$0.2	$0.2	$0.8	$1.3
West Virginia	$0.0	-$0.1	-$2.1	-$5.0	-$9.3
Wisconsin	$0.0	$0.0	-$0.1	-$0.6	-$1.8
Wyoming	$0.0	$0.0	-$0.2	-$0.3	-$0.9

Table E-3. Change in GDP Contribution by State and Year (in Billions)

Change in GDP - 1% Case (Alabama to Montana)

Year	AL	AZ	AR	CA	CO	CT	DE	DC	FL	GA	ID	IL	IN	IA	KS	KY	LA	ME	MD	MA	MI	MN	MS	MO	MT
2010	$0.0	$0.2	$0.0	$0.3	$0.0	$0.0	$0.0	$0.0	-$0.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2011	-$0.1	$0.0	$0.0	$0.5	$0.0	$0.0	$0.0	$0.0	-$0.3	-$0.2	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	-$0.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2012	-$0.1	-$0.2	$0.0	$0.0	-$0.1	-$0.1	$0.0	$0.0	-$0.6	-$0.3	$0.0	$0.0	$0.0	$0.0	$0.0	-$0.1	-$0.1	$0.0	-$0.1	-$0.1	-$0.1	$0.0	$0.0	$0.0	$0.0
2013	-$0.1	-$0.1	$0.0	$0.3	$0.0	-$0.1	$0.0	$0.0	-$0.7	-$0.4	$0.0	$0.0	$0.0	$0.0	$0.0	-$0.1	-$0.1	$0.0	-$0.1	-$0.1	-$0.1	$0.0	$0.0	$0.0	$0.0
2014	-$0.2	-$0.2	-$0.1	$0.0	-$0.1	-$0.1	$0.0	$0.0	-$1.0	-$0.6	$0.0	$0.0	-$0.1	$0.1	-$0.1	-$0.1	-$0.1	$0.0	-$0.2	-$0.1	-$0.1	$0.0	$0.0	$0.0	$0.0
2015	-$0.2	-$1.3	-$0.1	-$1.2	-$2.3	-$0.2	-$0.1	-$0.1	-$1.6	-$0.7	-$0.1	-$0.1	-$0.1	$0.0	-$0.4	-$0.2	-$0.3	$0.0	-$0.3	-$0.3	-$0.2	-$0.2	-$0.1	-$0.2	$0.0
2016	-$0.3	-$1.7	-$0.1	-$1.0	-$0.4	-$0.1	-$0.1	$0.0	-$1.5	-$0.8	$0.0	-$0.2	-$0.1	$0.0	-$0.1	-$0.2	-$0.2	$0.0	-$0.2	-$0.2	-$0.2	-$0.1	-$0.1	-$0.1	$0.0
2017	-$0.2	-$1.0	-$0.1	-$0.4	-$0.2	-$0.1	$0.0	$0.0	-$1.5	-$0.9	$0.0	$0.0	-$0.1	$0.0	-$0.1	-$0.2	-$0.2	$0.0	-$0.2	-$0.1	-$0.1	$0.0	-$0.1	$0.0	$0.0
2018	-$0.3	-$1.8	-$0.2	-$0.8	-$1.2	-$0.2	-$0.1	-$0.1	-$1.9	-$1.1	$0.0	-$0.3	-$0.2	$0.0	-$0.4	-$0.3	-$0.3	$0.0	-$0.3	-$0.3	-$0.3	-$0.2	-$0.1	-$0.2	$0.0
2019	-$0.2	-$0.6	-$0.1	-$0.8	-$0.2	-$0.1	$0.0	$0.0	-$1.6	-$1.1	$0.0	$0.0	$0.0	$0.0	-$0.1	-$0.2	-$0.2	$0.0	-$0.2	-$0.1	-$0.1	$0.0	-$0.1	$0.0	$0.0
2020	-$0.2	-$0.5	-$0.1	-$0.4	-$0.1	-$0.1	$0.0	$0.0	-$1.6	-$1.0	$0.0	$0.1	$0.0	$0.0	-$0.1	-$0.2	-$0.1	$0.0	-$0.2	$0.0	-$0.1	$0.0	$0.0	$0.0	$0.0
2021	-$0.3	-$2.0	-$0.1	-$1.2	-$0.8	-$0.1	-$0.1	-$0.1	-$1.9	-$1.1	$0.0	$0.0	-$0.1	$0.0	-$0.1	-$0.2	-$0.2	$0.0	-$0.3	-$0.2	-$0.2	-$0.1	-$0.1	-$0.1	$0.0
2022	-$0.3	-$1.2	-$0.1	-$0.3	-$0.5	-$0.1	-$0.1	-$0.1	-$1.8	-$1.1	$0.0	$0.1	$0.0	$0.0	-$0.1	-$0.2	-$0.2	$0.0	-$0.2	-$0.1	-$0.1	$0.0	-$0.1	$0.0	$0.0
2023	-$0.3	-$2.2	-$0.1	-$1.0	-$0.2	-$0.1	-$0.1	-$0.1	-$1.8	-$1.1	$0.0	$0.2	-$0.1	$0.0	-$0.1	-$0.2	-$0.2	$0.0	-$0.3	-$0.1	$0.0	$0.0	-$0.1	$0.0	$0.0
2024	-$0.3	-$1.1	-$0.1	-$0.5	-$0.1	-$0.1	-$0.1	$0.0	-$1.7	-$1.1	$0.0	$0.2	$0.0	$0.0	-$0.1	-$0.2	-$0.1	$0.0	-$0.2	$0.0	-$0.1	$0.0	$0.0	$0.1	$0.0
2025	-$0.3	-$1.8	-$0.1	-$1.0	-$0.1	-$0.1	-$0.1	-$0.1	-$2.0	-$1.2	$0.0	$0.2	-$0.1	$0.0	-$0.1	-$0.2	-$0.1	$0.0	-$0.3	-$0.1	-$0.1	$0.0	$0.0	$0.1	$0.0
2026	-$0.3	-$2.4	-$0.1	-$1.2	-$0.2	-$0.1	-$0.1	-$0.1	-$2.1	-$1.3	$0.0	$0.2	-$0.1	$0.0	-$0.1	-$0.2	-$0.2	$0.0	-$0.3	-$0.1	-$0.1	$0.0	-$0.1	$0.0	$0.0
2027	-$0.2	-$2.1	-$0.1	-$2.2	-$0.2	-$0.2	-$0.1	-$0.1	-$2.2	-$1.3	$0.0	$0.1	-$0.1	$0.0	-$0.1	-$0.3	-$0.2	$0.0	-$0.4	-$0.2	-$0.2	-$0.1	-$0.1	$0.0	$0.0
2028	-$0.3	-$1.9	-$0.2	-$2.0	-$0.2	-$0.2	-$0.1	-$0.1	-$2.7	-$1.6	$0.0	$0.0	-$0.2	$0.0	-$0.2	-$0.4	-$0.2	$0.0	-$0.5	-$0.2	-$0.3	-$0.1	-$0.1	-$0.1	$0.0
2029	-$0.6	-$2.9	-$0.3	-$3.8	-$2.4	-$0.4	-$0.1	-$0.2	-$3.2	-$2.0	$0.0	-$0.3	-$0.4	-$0.1	-$0.5	-$1.2	-$0.5	$0.0	-$0.7	-$0.5	-$0.5	-$0.3	-$0.2	-$0.3	-$0.1
2030	-$0.6	-$2.5	-$0.3	-$2.2	-$1.6	-$0.3	-$0.1	-$0.1	-$3.0	-$2.0	$0.0	$0.0	-$0.5	$0.0	-$0.3	-$0.5	-$0.4	$0.0	-$0.6	-$0.3	-$0.3	-$0.1	-$0.1	-$0.1	$0.0
2031	-$0.4	-$2.0	-$0.2	-$1.9	-$0.8	-$0.2	-$0.1	-$0.1	-$2.9	-$1.8	$0.0	$0.1	-$0.2	$0.0	-$0.3	-$0.5	-$0.3	$0.0	-$0.5	-$0.2	-$0.2	-$0.3	-$0.1	-$0.1	$0.0
2032	-$0.6	-$1.8	-$0.2	-$1.2	-$0.3	-$0.2	-$0.1	-$0.1	-$3.0	-$2.1	$0.0	-$0.2	-$0.8	-$0.1	-$0.2	-$0.6	-$0.3	$0.0	-$0.6	-$0.2	-$0.4	-$0.3	-$0.1	$0.0	$0.0
2033	-$0.5	-$2.0	-$0.3	-$1.4	-$0.8	-$0.3	-$0.1	-$0.1	-$3.3	-$2.2	$0.0	-$0.3	-$0.9	-$0.1	-$0.4	-$0.7	-$0.4	$0.0	-$0.6	-$0.3	-$0.4	-$0.2	-$0.2	-$0.1	$0.0
2034	-$0.6	-$2.3	-$0.3	-$1.3	-$0.5	-$0.2	-$0.1	-$0.1	-$3.3	-$2.3	$0.0	-$0.2	-$0.5	-$0.1	-$0.2	-$0.6	-$0.3	$0.0	-$0.5	-$0.2	-$0.7	-$0.3	-$0.2	-$0.1	$0.0
2035	-$0.8	-$3.2	-$0.5	-$2.9	-$1.3	-$0.4	-$0.2	-$0.2	-$4.3	-$2.9	$0.0	-$1.5	-$1.6	-$0.3	-$0.6	-$2.1	-$0.6	$0.0	-$0.8	-$0.5	-$1.1	-$0.5	-$0.3	-$0.7	-$0.1
2036	-$0.9	-$3.7	-$0.5	-$3.9	-$2.1	-$0.5	-$0.2	-$0.2	-$4.2	-$3.0	$0.0	-$2.0	-$1.9	-$0.5	-$0.7	-$2.5	-$0.6	$0.0	-$0.9	-$0.6	-$1.0	-$0.8	-$0.3	-$0.6	-$0.1
2037	-$0.8	-$4.2	-$0.4	-$3.8	-$0.8	-$0.2	-$0.1	-$0.1	-$3.8	-$2.7	$0.0	-$0.5	-$0.6	-$0.3	-$0.3	-$0.8	-$0.4	$0.0	-$0.5	-$0.2	-$1.0	-$0.8	-$0.2	-$0.3	$0.0
2038	-$0.7	-$3.8	-$0.4	-$2.9	-$0.3	-$0.3	-$0.1	-$0.2	-$3.8	-$2.7	$0.1	-$0.6	-$1.0	-$0.3	-$0.3	-$1.5	-$0.4	$0.0	-$0.7	-$0.2	-$0.7	-$1.0	-$0.2	-$0.3	$0.0
2039	-$0.8	-$1.9	-$0.4	-$2.8	-$0.1	-$0.3	-$0.2	-$0.2	-$4.0	-$2.9	$0.1	-$0.9	-$1.7	-$0.3	-$0.3	-$2.3	-$0.4	$0.0	-$0.8	-$0.2	-$0.9	-$0.7	-$0.2	-$0.3	$0.0
2040	-$0.9	-$5.2	-$0.5	-$5.1	-$1.5	-$0.5	-$0.2	-$0.3	-$4.8	-$3.3	$0.1	-$1.3	-$2.0	-$0.4	-$0.4	-$2.9	-$0.6	$0.0	-$1.0	-$0.5	-$1.5	-$0.7	-$0.3	-$0.5	-$0.1
2041	-$1.1	-$4.2	-$0.6	-$6.1	-$1.4	-$0.7	-$0.2	-$0.3	-$5.4	-$3.7	$0.0	-$2.4	-$2.5	-$0.6	-$0.6	-$4.8	-$0.7	-$0.1	-$1.3	-$0.8	-$1.8	-$1.6	-$0.4	-$0.7	-$0.1
2042	-$1.1	-$4.9	-$0.5	-$3.4	-$1.1	-$0.5	-$0.2	-$0.3	-$5.1	-$3.7	$0.1	-$1.5	-$2.1	-$0.5	-$0.4	-$2.9	-$0.6	$0.0	-$1.2	-$0.6	-$1.8	-$1.0	-$0.3	-$0.5	-$0.1
2043	-$1.4	-$5.0	-$0.6	-$5.0	-$1.9	-$0.6	-$0.3	-$0.3	-$5.5	-$4.2	$0.0	-$1.4	-$2.0	-$0.4	-$0.4	-$3.6	-$0.8	$0.0	-$1.4	-$0.7	-$1.7	-$0.7	-$0.4	-$0.5	-$0.1
2044	-$1.5	-$6.9	-$0.8	-$7.0	-$2.1	-$0.8	-$0.3	-$0.3	-$6.1	-$4.4	$0.0	-$3.5	-$3.2	-$0.7	-$0.7	-$4.4	-$0.9	-$0.1	-$1.4	-$0.9	-$2.6	-$1.5	-$0.5	-$1.2	-$0.1
2045	-$1.4	-$3.9	-$0.7	-$6.3	-$0.9	-$0.7	-$0.3	-$0.4	-$6.0	-$4.5	$0.1	-$2.9	-$3.1	-$0.7	-$0.7	-$5.4	-$0.9	$0.0	-$1.5	-$0.8	-$2.2	-$1.3	-$0.5	-$0.8	-$0.1
2046	-$1.6	-$4.6	-$0.8	-$7.0	-$1.8	-$0.8	-$0.3	-$0.4	-$6.5	-$4.9	$0.1	-$4.7	-$3.8	-$2.4	-$0.9	-$5.0	-$1.0	-$0.1	-$1.6	-$0.9	-$3.4	-$2.6	-$0.5	-$1.4	-$0.1
2047	-$1.9	-$4.3	-$1.0	-$5.0	-$1.6	-$1.0	-$0.4	-$0.5	-$7.3	-$5.6	$0.2	-$5.9	-$4.8	-$1.2	-$1.0	-$8.8	-$1.3	-$0.1	-$2.0	-$1.2	-$3.8	-$2.8	-$0.6	-$1.9	-$0.1
2048	-$1.9	-$2.8	-$0.9	-$0.5	-$0.8	-$0.8	-$0.3	-$0.5	-$7.1	-$5.7	$0.3	-$5.6	-$4.5	-$1.1	-$0.8	-$7.2	-$1.2	$0.0	-$1.9	-$0.9	-$3.7	-$1.6	-$0.6	-$1.5	$0.0
2049	-$1.8	-$4.5	-$0.9	-$0.5	-$0.2	-$0.5	-$0.3	-$0.4	-$6.9	-$5.5	$0.3	-$2.8	-$3.0	-$0.6	-$0.5	-$4.5	-$0.9	$0.0	-$1.6	-$0.6	-$2.9	-$1.0	-$0.5	-$0.6	$0.0
2050	-$2.2	-$5.8	-$1.2	-$2.5	-$2.4	-$0.9	-$0.3	-$0.5	-$7.8	-$6.2	$0.1	-$5.2	-$4.7	-$1.1	-$1.0	-$6.8	-$1.3	-$0.1	-$1.9	-$1.1	-$3.3	-$2.0	-$0.7	-$1.7	-$0.1

Table E-4. Change in GDP Contribution by State and Year (in Billions)

Change in GDP - 1% Case (Nebraska to Wyoming)

Year	NE	NV	NH	NJ	NM	NY	NC	ND	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI	WY	U.S.
2010	$0.0	$0.0	$0.0	$0.0	$0.0	-$0.1	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.5
2011	$0.0	$0.0	$0.0	-$0.1	$0.0	-$0.3	-$0.1	$0.0	$0.0	$0.0	$0.0	-$0.1	$0.0	$0.0	$0.0	-$0.1	-$0.2	$0.0	$0.0	-$0.1	$0.0	$0.0	$0.0	$0.0	-$1.4
2012	$0.0	-$0.2	$0.0	-$0.2	-$0.2	-$0.6	-$0.2	$0.0	-$0.1	-$0.7	$0.0	-$0.3	$0.0	-$0.1	$0.0	-$0.1	-$0.7	$0.0	$0.0	-$0.2	$0.0	$0.0	$0.0	-$0.1	-$5.8
2013	$0.0	-$0.4	$0.0	-$0.2	-$0.1	-$0.6	-$0.3	$0.0	-$0.1	-$0.1	$0.1	-$0.3	$0.0	-$0.1	$0.0	-$0.2	-$0.5	$0.0	$0.0	-$0.2	$0.1	$0.0	$0.0	$0.0	-$4.9
2014	$0.0	-$0.4	$0.0	-$0.3	-$0.2	-$0.9	-$0.4	$0.0	-$0.1	-$0.2	$0.0	-$0.5	$0.0	-$0.2	$0.0	-$0.2	-$0.9	$0.0	$0.0	-$0.3	$0.1	$0.0	$0.0	$0.0	-$8.0
2015	-$0.1	-$1.3	$0.0	-$0.6	-$1.2	-$1.7	-$0.5	$0.0	-$0.2	-$3.1	$0.0	-$0.7	$0.0	-$0.1	$0.0	-$0.4	-$2.1	-$0.5	$0.0	-$0.4	-$0.1	-$0.1	-$0.1	-$0.6	-$24.3
2016	-$0.1	-$1.6	$0.0	-$0.5	-$1.0	-$1.4	-$0.5	$0.0	-$0.2	-$0.4	$0.0	-$0.6	$0.0	-$0.1	$0.0	-$0.5	-$1.8	-$0.7	$0.0	-$0.4	$0.0	-$0.1	-$0.1	-$0.1	-$18.0
2017	-$0.1	-$0.5	$0.0	-$0.4	-$0.2	-$1.0	-$0.5	$0.0	-$0.1	-$0.7	$0.2	-$0.5	$0.0	-$0.1	$0.0	-$0.4	-$1.4	-$0.2	$0.0	-$0.4	$0.2	-$0.1	$0.0	-$0.1	-$11.8
2018	-$0.1	-$0.9	$0.0	-$0.6	-$1.2	-$2.0	-$0.7	$0.0	-$0.3	-$3.6	$0.1	-$0.8	$0.0	-$0.2	$0.0	-$0.6	-$2.5	-$0.4	$0.0	-$0.5	$0.1	-$0.1	-$0.1	-$0.5	-$25.7
2019	-$0.1	-$0.5	$0.0	-$0.4	-$0.2	-$1.1	-$0.7	$0.0	-$0.1	-$1.4	$0.1	-$0.6	$0.0	-$0.3	$0.0	-$0.5	-$1.8	-$0.2	$0.0	-$0.5	$0.2	-$0.1	$0.0	-$0.1	-$14.0
2020	$0.0	-$0.1	$0.0	-$0.3	-$0.2	-$1.0	-$0.6	$0.0	$0.0	-$0.4	$0.2	-$0.6	$0.0	-$0.2	$0.0	-$0.4	-$1.3	-$0.1	$0.0	-$0.4	$0.2	-$0.1	$0.0	$0.0	-$10.2
2021	-$0.1	-$1.4	$0.0	-$0.5	-$1.0	-$1.6	-$0.7	$0.0	-$0.1	-$0.4	$0.1	-$0.6	$0.0	-$0.2	$0.0	-$0.5	-$2.0	-$0.8	$0.0	-$0.5	$0.1	-$0.1	-$0.1	-$0.4	-$19.9
2022	-$0.1	-$0.5	$0.0	-$0.4	-$1.0	-$1.3	-$0.7	$0.0	-$0.1	-$1.4	$0.2	-$0.7	$0.0	-$0.2	$0.0	-$0.6	-$1.8	-$0.2	$0.0	-$0.5	$0.2	-$0.1	$0.0	-$0.1	-$15.7
2023	-$0.1	-$0.2	$0.0	-$0.5	-$1.3	-$1.6	-$0.7	$0.0	-$0.3	-$0.4	$0.2	-$0.6	$0.0	-$0.2	$0.0	-$0.5	-$1.9	-$0.2	$0.0	-$0.5	$0.2	-$0.1	$0.1	-$0.1	-$16.3
2024	$0.0	-$1.1	$0.0	-$0.4	-$0.6	-$1.2	-$0.7	$0.0	-$0.2	-$0.3	$0.3	-$0.7	$0.0	-$0.2	$0.0	-$0.5	-$1.7	-$0.2	$0.0	-$0.5	$0.3	-$0.1	$0.0	$0.0	-$13.3
2025	-$0.1	-$1.4	$0.0	-$0.5	-$0.7	-$1.7	-$0.8	$0.0	-$0.2	-$0.3	$0.1	-$0.9	$0.0	-$0.3	$0.0	-$0.6	-$1.7	-$0.4	$0.0	-$0.5	$0.1	-$0.1	$0.0	-$0.2	-$17.3
2026	-$0.1	-$2.0	$0.0	-$0.6	-$1.0	-$1.8	-$0.8	$0.0	-$0.3	-$0.3	$0.2	-$0.9	$0.0	-$0.3	$0.0	-$0.7	-$1.9	-$0.7	$0.0	-$0.6	$0.2	-$0.1	$0.0	-$0.1	-$20.4
2027	-$0.1	-$2.5	$0.0	-$0.7	-$0.9	-$2.3	-$0.8	$0.0	-$0.4	-$0.6	$0.8	-$1.0	$0.0	-$0.2	$0.0	-$0.9	-$2.1	-$0.8	$0.0	-$0.7	$0.2	-$1.2	$0.0	-$0.2	-$24.9
2028	-$0.1	-$1.4	$0.0	-$0.8	-$1.3	-$2.6	-$1.1	$0.0	-$0.6	-$2.7	$0.2	-$1.1	$0.0	-$0.4	$0.0	-$1.2	-$2.7	-$0.3	$0.0	-$0.9	$0.3	-$1.6	-$0.1	-$0.1	-$30.4
2029	-$0.2	-$2.5	-$0.1	-$1.2	-$1.7	-$4.1	-$1.3	-$0.1	-$1.0	-$2.6	$0.1	-$1.6	$0.0	-$0.4	-$0.1	-$1.5	-$4.4	-$1.4	$0.0	-$1.2	$0.0	-$2.7	-$0.2	-$0.9	-$50.4
2030	-$0.1	-$1.0	$0.0	-$1.0	-$1.6	-$3.1	-$1.2	$0.0	-$1.1	-$2.9	$0.2	-$1.4	$0.0	-$0.5	$0.0	-$1.2	-$3.6	-$0.6	$0.0	-$1.1	$0.2	-$2.1	-$0.1	-$0.2	-$38.4
2031	-$0.1	-$1.2	$0.0	-$0.8	-$1.2	-$2.5	-$1.1	$0.0	-$0.5	-$2.3	$0.3	-$1.2	$0.0	-$0.3	$0.0	-$1.4	-$3.3	-$0.5	$0.0	-$0.9	$0.4	-$0.6	-$0.1	-$0.1	-$30.8
2032	-$0.1	-$1.2	$0.0	-$0.9	-$1.0	-$2.9	-$1.4	-$0.1	-$1.2	-$1.0	$0.3	-$1.4	$0.0	-$0.5	$0.0	-$1.5	-$3.5	-$0.5	$0.0	-$1.1	$0.4	-$2.3	-$0.1	-$0.2	-$33.5
2033	-$0.1	-$0.6	$0.0	-$1.0	-$1.2	-$3.1	-$1.5	$0.0	-$1.2	-$2.7	$0.3	-$1.4	$0.0	-$0.5	$0.0	-$1.8	-$3.8	-$0.3	$0.0	-$1.2	$0.4	-$1.7	-$0.2	-$0.1	-$37.1
2034	-$0.1	-$2.1	$0.0	-$0.8	-$0.8	-$2.8	-$1.5	-$0.1	-$0.6	-$0.7	$0.3	-$1.4	$0.0	-$0.5	$0.0	-$1.6	-$3.5	-$1.0	$0.0	-$1.1	$0.4	-$0.3	-$0.4	-$0.8	-$34.2
2035	-$0.2	-$2.3	-$0.1	-$1.4	-$1.5	-$5.1	-$1.9	-$0.1	-$2.0	-$3.6	$0.3	-$1.9	$0.0	-$0.7	-$0.1	-$2.2	-$4.9	-$1.0	-$0.1	-$1.6	$0.3	-$3.6	-$0.3	-$0.2	-$61.3
2036	-$0.3	-$2.5	-$0.1	-$1.5	-$1.4	-$5.4	-$2.0	-$0.1	-$2.5	-$2.5	$0.3	-$2.1	$0.0	-$0.7	-$0.1	-$2.4	-$5.5	-$1.3	$0.0	-$1.7	$0.3	-$3.7	-$0.5	-$0.5	-$68.0
2037	-$0.2	-$2.4	$0.0	-$0.9	-$1.2	-$3.4	-$1.6	-$0.1	-$0.8	-$0.9	$0.4	-$1.6	$0.0	-$0.7	$0.0	-$1.6	-$4.7	-$1.3	$0.0	-$1.2	$0.4	-$0.6	-$0.5	-$0.2	-$45.9
2038	-$0.2	-$1.9	$0.0	-$1.1	-$1.0	-$3.9	-$1.7	-$0.1	-$1.3	-$1.3	$0.5	-$1.8	$0.0	-$0.7	$0.0	-$2.0	-$4.3	-$1.0	$0.0	-$1.4	$0.7	-$3.0	-$0.5	-$0.2	-$48.6
2039	-$0.2	-$1.5	$0.0	-$1.2	-$0.9	-$4.3	-$1.9	-$0.1	-$2.2	-$1.7	$0.6	-$2.0	$0.0	-$0.8	$0.0	-$2.2	-$4.1	-$0.5	$0.0	-$1.6	$0.9	-$3.4	-$0.4	-$0.1	-$50.1
2040	-$0.3	-$3.6	-$0.1	-$1.6	-$1.7	-$6.0	-$2.2	-$0.1	-$2.9	-$1.5	$0.6	-$2.5	$0.0	-$0.8	-$0.1	-$2.9	-$5.4	-$1.7	-$0.1	-$1.9	$0.8	-$5.0	-$0.6	-$0.3	-$74.3
2041	-$0.4	-$3.4	-$0.1	-$2.1	-$1.3	-$7.6	-$2.5	-$0.3	-$3.7	-$1.8	$0.6	-$3.2	-$0.1	-$0.9	-$0.1	-$3.3	-$6.0	-$1.4	-$0.1	-$2.4	$0.7	-$7.3	-$0.9	-$0.6	-$90.3
2042	-$0.3	-$2.0	-$0.1	-$1.8	-$1.3	-$6.4	-$2.6	-$0.1	-$3.3	-$1.1	$0.7	-$3.0	$0.0	-$0.9	-$0.1	-$3.1	-$5.6	-$1.7	-$0.1	-$2.2	$0.9	-$6.6	-$0.8	-$0.7	-$76.6
2043	-$0.3	-$2.5	-$0.1	-$2.1	-$1.6	-$7.3	-$2.9	-$0.1	-$3.6	-$1.3	$0.7	-$3.4	-$0.1	-$1.0	-$0.1	-$3.2	-$6.4	-$1.9	-$0.1	-$2.5	$0.8	-$6.3	-$0.6	-$0.6	-$85.6
2044	-$0.4	-$4.1	-$0.1	-$2.3	-$1.9	-$8.5	-$3.0	-$0.2	-$3.8	-$2.5	$0.7	-$3.7	-$0.1	-$1.1	-$0.1	-$3.9	-$7.6	-$2.6	-$0.1	-$2.6	$0.7	-$5.1	-$1.2	-$1.0	-$106.2
2045	-$0.4	-$3.7	-$0.1	-$2.3	-$1.2	-$8.3	-$3.2	-$0.2	-$4.6	-$2.0	$0.9	-$3.8	-$0.1	-$1.1	-$0.1	-$4.1	-$7.2	-$1.7	-$0.1	-$2.9	$1.0	-$9.4	-$1.0	-$0.6	-$101.8
2046	-$0.6	-$3.7	-$0.2	-$2.4	-$1.7	-$9.1	-$3.4	-$0.3	-$4.6	-$2.9	$0.9	-$3.8	-$0.1	-$1.3	-$0.2	-$4.3	-$8.1	-$2.0	-$0.1	-$2.9	$1.1	-$8.7	-$1.6	-$1.1	-$116.1
2047	-$0.6	-$2.2	-$0.2	-$3.0	-$1.4	-$10.8	-$4.0	-$0.3	-$6.1	-$3.3	$1.0	-$4.7	-$0.1	-$1.5	-$0.2	-$4.9	-$9.1	-$1.7	-$0.1	-$3.6	$1.3	-$10.4	-$2.1	-$0.5	-$132.1
2048	-$0.5	-$0.5	-$0.2	-$2.7	-$1.6	-$9.5	-$4.0	-$0.2	-$5.9	-$2.9	$1.2	-$4.6	-$0.1	-$1.5	-$0.1	-$4.9	-$8.5	-$1.0	-$0.1	-$3.5	$1.6	-$10.1	-$1.9	-$0.4	-$113.5
2049	-$0.3	-$1.2	-$0.1	-$2.1	-$1.6	-$7.4	-$3.7	-$0.1	-$4.6	-$2.4	$1.2	-$3.8	$0.0	-$1.4	-$0.1	-$4.6	-$7.6	-$1.1	-$0.1	-$3.0	$1.7	-$8.0	-$1.3	-$0.3	-$92.7
2050	-$0.6	-$2.4	-$0.2	-$2.9	-$2.4	-$10.4	-$4.2	-$0.2	-$5.8	-$3.6	$1.1	-$4.8	-$0.1	-$1.6	-$0.2	-$5.3	-$9.8	-$1.8	-$0.2	-$3.6	$1.3	-$9.3	-$1.8	-$0.9	-$130.0

Table E-5. Change in Employment by State (1% Case)

Change in Employment (1K Labor Years) - 1% Case

Region	2010	2020	2030	2040	2050
United States	**-0.7**	**-104.5**	**-307.1**	**-474.3**	**-688.7**
Alabama	-0.2	-2.9	-5.3	-7.7	-13.6
Arizona	1.5	-4.6	-20.1	-33.7	-30.4
Arkansas	0.0	-1.2	-2.5	-3.9	-7.2
California	2.0	-3.9	-15.5	-31.8	-7.6
Colorado	0.2	-0.6	-11.8	-9.1	-12.5
Connecticut	0.0	-0.3	-1.2	-1.9	-2.9
Delaware	0.0	-0.4	-0.8	-1.1	-1.6
D.C.	0.0	-0.1	-0.5	-0.9	-1.5
Florida	-1.6	-19.3	-28.5	-37.0	-49.2
Georgia	-0.6	-11.2	-16.5	-22.1	-32.4
Idaho	0.0	0.3	0.1	0.4	0.8
Illinois	0.2	1.3	-0.1	-6.1	-24.0
Indiana	0.0	0.1	-4.2	-13.2	-25.8
Iowa	0.1	0.6	-0.4	-2.4	-6.3
Kansas	0.1	-0.7	-2.0	-2.8	-6.3
Kentucky	-0.1	-2.0	-4.9	-21.1	-40.3
Louisiana	0.0	-1.5	-3.5	-4.7	-8.2
Maine	0.0	0.0	-0.2	-0.3	-0.5
Maryland	-0.2	-2.1	-4.6	-6.5	-10.0
Massachusetts	0.0	-0.3	-1.6	-2.4	-4.1
Michigan	0.0	-0.5	-2.4	-8.4	-15.8
Minnesota	0.2	0.2	-0.8	-3.7	-9.2
Mississippi	0.0	-0.5	-1.5	-2.5	-4.8
Missouri	0.1	0.1	-1.0	-2.7	-9.2

Region	2010	2020	2030	2040	2050
Montana	0.0	0.2	-0.1	-0.3	-0.5
Nebraska	0.1	-0.2	-1.0	-2.0	-3.3
Nevada	0.3	-1.1	-6.4	-18.8	-10.3
New Hampshire	0.0	-0.1	-0.3	-0.6	-1.0
New Jersey	-0.4	-2.6	-5.7	-7.9	-11.5
New Mexico	0.0	-2.3	-14.9	-12.7	-15.4
New York	-0.7	-6.7	-15.0	-22.9	-32.9
North Carolina	-0.4	-7.2	-11.5	-16.2	-24.6
North Dakota	0.0	-0.1	-0.4	-0.7	-1.2
Ohio	0.0	-0.1	-8.6	-19.3	-32.4
Oklahoma	0.1	-4.5	-25.2	-11.1	-23.7
Oregon	0.1	2.0	2.4	4.6	6.4
Pennsylvania	-0.5	-5.7	-11.9	-17.4	-26.2
Rhode Island	0.0	0.0	-0.2	-0.2	-0.4
South Carolina	-0.1	-3.4	-5.3	-7.3	-11.2
South Dakota	0.0	0.1	-0.3	-0.5	-1.0
Tennessee	-0.2	-4.9	-10.7	-21.4	-31.3
Texas	-0.4	-14.2	-31.8	-36.0	-53.8
Utah	0.1	-1.4	-5.1	-12.3	-10.6
Vermont	0.0	0.0	-0.3	-0.8	-1.2
Virginia	-0.4	-4.3	-8.9	-12.5	-18.7
Washington	0.1	2.3	2.6	5.9	7.6
West Virginia	0.0	-0.7	-17.2	-33.7	-54.2
Wisconsin	0.2	0.0	-0.5	-3.5	-9.5
Wyoming	0.0	-0.4	-1.5	-1.9	-5.6

Table E-6. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Accommodation and Food Services ($M)

Region	2020	2030	2040	2050
United States	**-$383.2**	**-$804.3**	**-$1,311.1**	**-$1,758.0**
Alabama	-$8.6	-$13.5	-$23.3	-$45.3
Arizona	-$9.8	-$50.2	-$90.6	-$83.2
Arkansas	-$1.2	-$2.4	-$6.1	-$13.5
California	$0.0	-$29.4	-$142.0	$149.4
Colorado	$4.9	-$8.6	$0.0	-$3.7
Connecticut	$7.3	$11.0	$14.7	$23.3
Delaware	-$1.2	-$1.2	-$2.4	-$2.4
District of Columbia	$2.4	$2.4	$1.2	$0.0
Florida	-$151.8	-$225.3	-$318.3	-$466.4
Georgia	-$53.9	-$77.1	-$111.4	-$173.8
Idaho	$2.4	$2.4	$6.1	$8.6
Illinois	$7.3	$11.0	$4.9	-$28.2
Indiana	$3.7	$3.7	-$6.1	-$23.3
Iowa	$1.2	$1.2	-$1.2	-$6.1
Kansas	-$1.2	-$1.2	-$2.4	-$7.3
Kentucky	-$8.6	-$15.9	-$38.0	-$77.1
Louisiana	-$4.9	-$7.3	-$9.8	-$24.5
Maine	$1.2	$1.2	$2.4	$2.4
Maryland	-$8.6	-$13.5	-$17.1	-$26.9
Massachusetts	$4.9	$7.3	$9.8	$13.5
Michigan	$0.0	$0.0	-$7.3	-$18.4
Minnesota	$0.0	$1.2	-$2.4	-$12.2
Mississippi	-$1.2	-$2.4	-$7.3	-$17.1
Missouri	$2.4	$4.9	$4.9	-$7.3
Montana	$1.2	$1.2	$2.4	$2.4
Nebraska	$0.0	$0.0	-$2.4	-$3.7
Nevada	$1.2	-$15.9	-$56.3	-$53.9
New Hampshire	$1.2	$1.2	$1.2	$2.4
New Jersey	$1.2	-$2.4	$0.0	$1.2
New Mexico	-$4.9	-$24.5	-$25.7	-$31.8
New York	-$23.3	-$38.0	-$51.4	-$60.0
North Carolina	-$25.7	-$40.4	-$58.8	-$89.4
North Dakota	$0.0	$0.0	-$1.2	-$2.4
Ohio	$6.1	$2.4	-$7.3	-$24.5
Oklahoma	-$12.2	-$34.3	-$29.4	-$51.4
Oregon	$8.6	$12.2	$25.7	$35.5
Pennsylvania	-$18.4	-$34.3	-$45.3	-$66.1
Rhode Island	$1.2	$1.2	$2.4	$3.7
South Carolina	-$22.0	-$33.1	-$51.4	-$88.1
South Dakota	$0.0	$0.0	-$1.2	-$2.4
Tennessee	-$19.6	-$33.1	-$62.4	-$110.2
Texas	-$60.0	-$138.3	-$161.6	-$273.0
Utah	$0.0	-$7.3	-$18.4	-$18.4
Vermont	$0.0	$0.0	$0.0	$0.0
Virginia	-$19.6	-$31.8	-$42.8	-$63.7
Washington	$14.7	$20.8	$45.3	$58.8
West Virginia	-$3.7	-$18.4	-$39.2	-$73.5
Wisconsin	$0.0	$1.2	-$2.4	-$12.2
Wyoming	$0.0	-$1.2	-$2.4	-$7.3

Table E-7. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Administrative and Waste Services ($M)

Region	2020	2030	2040	2050
United States	**-$252.2**	**-$1,001.4**	**-$1,734.7**	**-$2,634.6**
Alabama	-$4.9	-$11.0	-$18.4	-$31.8
Arizona	-$14.7	-$74.7	-$138.3	-$148.1
Arkansas	-$1.2	-$3.7	-$6.1	-$11.0
California	-$15.9	-$72.2	-$159.1	-$102.8
Colorado	-$4.9	-$42.8	-$39.2	-$58.8
Connecticut	-$2.4	-$7.3	-$12.2	-$19.6
Delaware	-$1.2	-$2.4	-$3.7	-$7.3
District of Columbia	-$1.2	-$4.9	-$8.6	-$14.7
Florida	-$56.3	-$123.6	-$193.4	-$293.8
Georgia	-$26.9	-$53.9	-$84.5	-$132.2
Idaho	$0.0	-$1.2	-$1.2	$0.0
Illinois	$6.1	-$3.7	-$38.0	-$115.1
Indiana	$1.2	-$11.0	-$35.5	-$72.2
Iowa	$6.1	$1.2	-$4.9	-$13.5
Kansas	$0.0	-$6.1	-$8.6	-$19.6
Kentucky	-$1.2	-$8.6	-$35.5	-$69.8
Louisiana	-$2.4	-$9.8	-$14.7	-$26.9
Maine	$0.0	$0.0	-$1.2	-$1.2
Maryland	-$6.1	-$18.4	-$29.4	-$50.2
Massachusetts	-$2.4	-$9.8	-$17.1	-$33.1
Michigan	-$1.2	-$15.9	-$46.5	-$88.1
Minnesota	$4.9	-$1.2	-$12.2	-$31.8
Mississippi	-$1.2	-$2.4	-$4.9	-$9.8
Missouri	$1.2	-$3.7	-$9.8	-$29.4

Region	2020	2030	2040	2050
Montana	$0.0	$0.0	-$1.2	-$1.2
Nebraska	$4.9	$0.0	-$3.7	-$8.6
Nevada	-$3.7	-$22.0	-$62.4	-$38.0
New Hampshire	$0.0	-$1.2	-$2.4	-$6.1
New Jersey	-$11.0	-$30.6	-$51.4	-$80.8
New Mexico	-$4.9	-$34.3	-$31.8	-$42.8
New York	-$19.6	-$58.8	-$106.5	-$170.2
North Carolina	-$13.5	-$29.4	-$47.7	-$78.4
North Dakota	$1.2	$0.0	-$1.2	-$2.4
Ohio	-$1.2	-$29.4	-$68.6	-$123.6
Oklahoma	-$7.3	-$60.0	-$30.6	-$63.7
Oregon	$3.7	$4.9	$9.8	$15.9
Pennsylvania	-$11.0	-$31.8	-$52.6	-$83.2
Rhode Island	$0.0	-$1.2	-$1.2	-$2.4
South Carolina	-$7.3	-$15.9	-$23.3	-$36.7
South Dakota	$1.2	$0.0	$0.0	-$1.2
Tennessee	-$9.8	-$29.4	-$62.4	-$100.4
Texas	-$38.0	-$112.6	-$145.7	-$235.1
Utah	-$3.7	-$14.7	-$36.7	-$36.7
Vermont	$0.0	$0.0	-$1.2	-$1.2
Virginia	-$9.8	-$25.7	-$42.8	-$68.6
Washington	$2.4	$0.0	$6.1	$11.0
West Virginia	-$1.2	-$19.6	-$41.6	-$66.1
Wisconsin	$1.2	-$1.2	-$9.8	-$25.7
Wyoming	$0.0	-$1.2	-$2.4	-$6.1

Table E-8. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Arts, Entertainment, and Recreation ($M)

Region	2020	2030	2040	2050
United States	**-$74.7**	**-$307.3**	**-$696.4**	**-$1,236.2**
Alabama	-$1.2	-$2.4	-$4.9	-$12.2
Arizona	-$4.9	-$24.5	-$55.1	-$63.7
Arkansas	$0.0	-$1.2	-$2.4	-$4.9
California	-$3.7	-$25.7	-$62.4	-$11.0
Colorado	-$1.2	-$19.6	-$24.5	-$40.4
Connecticut	$0.0	-$1.2	-$2.4	-$3.7
Delaware	$0.0	-$1.2	-$2.4	-$4.9
District of Columbia	$0.0	-$1.2	-$1.2	-$3.7
Florida	-$22.0	-$56.3	-$110.2	-$198.3
Georgia	-$6.1	-$12.2	-$23.3	-$42.8
Idaho	$0.0	$0.0	$1.2	$3.7
Illinois	$2.4	$2.4	-$6.1	-$47.7
Indiana	$0.0	-$4.9	-$23.3	-$66.1
Iowa	$1.2	$0.0	-$2.4	-$9.8
Kansas	$0.0	-$1.2	-$1.2	-$4.9
Kentucky	$0.0	-$2.4	-$15.9	-$42.8
Louisiana	-$1.2	-$7.3	-$13.5	-$28.2
Maine	$0.0	$0.0	$0.0	$0.0
Maryland	-$1.2	-$4.9	-$8.6	-$18.4
Massachusetts	$0.0	$0.0	$0.0	-$1.2
Michigan	$0.0	-$1.2	-$13.5	-$36.7
Minnesota	$1.2	$1.2	-$3.7	-$14.7
Mississippi	$0.0	-$1.2	-$3.7	-$8.6
Missouri	$0.0	-$2.4	-$7.3	-$26.9
Montana	$0.0	$0.0	-$1.2	-$1.2
Nebraska	$0.0	$0.0	-$1.2	-$3.7
Nevada	-$2.4	-$13.5	-$49.0	-$35.5
New Hampshire	$0.0	$0.0	$0.0	-$1.2
New Jersey	-$2.4	-$4.9	-$9.8	-$18.4
New Mexico	-$1.2	-$8.6	-$12.2	-$17.1
New York	-$7.3	-$19.6	-$38.0	-$66.1
North Carolina	-$4.9	-$11.0	-$22.0	-$41.6
North Dakota	$0.0	$0.0	$0.0	-$1.2
Ohio	$0.0	-$6.1	-$24.5	-$57.5
Oklahoma	-$2.4	-$14.7	-$11.0	-$28.2
Oregon	$1.2	$3.7	$7.3	$14.7
Pennsylvania	-$3.7	-$11.0	-$22.0	-$42.8
Rhode Island	$0.0	$0.0	$0.0	$0.0
South Carolina	-$2.4	-$4.9	-$9.8	-$20.8
South Dakota	$0.0	$0.0	-$1.2	-$2.4
Tennessee	-$2.4	-$8.6	-$23.3	-$44.1
Texas	-$8.6	-$25.7	-$40.4	-$75.9
Utah	-$1.2	-$4.9	-$17.1	-$20.8
Vermont	$0.0	$0.0	$0.0	-$1.2
Virginia	-$2.4	-$7.3	-$14.7	-$29.4
Washington	$2.4	$6.1	$15.9	$29.4
West Virginia	$0.0	-$9.8	-$30.6	-$67.3
Wisconsin	$0.0	$1.2	-$2.4	-$12.2
Wyoming	$0.0	-$1.2	-$2.4	-$6.1

Table E-9. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Construction ($M)

Region	2020	2030	2040	2050
United States	**-$694.1**	**-$1,681.7**	**-$1,658.8**	**-$2,196.3**
Alabama	-$12.2	-$18.4	-$19.6	-$35.5
Arizona	-$52.6	-$115.1	-$134.7	-$104.1
Arkansas	-$4.9	-$7.3	-$8.6	-$14.7
California	-$40.4	-$115.1	-$153.0	-$7.3
Colorado	-$12.2	-$83.2	-$23.3	-$38.0
Connecticut	-$3.7	-$8.6	-$7.3	-$11.0
Delaware	-$2.4	-$4.9	-$4.9	-$7.3
District of Columbia	$0.0	-$1.2	-$1.2	-$2.4
Florida	-$113.9	-$139.6	-$143.2	-$195.9
Georgia	-$47.7	-$56.3	-$61.2	-$94.3
Idaho	$0.0	-$1.2	$2.4	$3.7
Illinois	-$1.2	-$18.4	-$49.0	-$124.9
Indiana	-$2.4	-$23.3	-$60.0	-$97.9
Iowa	$1.2	-$3.7	-$11.0	-$19.6
Kansas	-$6.1	-$11.0	-$4.9	-$15.9
Kentucky	-$6.1	-$20.8	-$58.8	-$95.5
Louisiana	-$11.0	-$20.8	-$18.4	-$35.5
Maine	-$1.2	-$1.2	-$1.2	-$1.2
Maryland	-$17.1	-$33.1	-$35.5	-$53.9
Massachusetts	-$4.9	-$11.0	-$9.8	-$17.1
Michigan	-$3.7	-$12.2	-$30.6	-$56.3
Minnesota	$0.0	-$6.1	-$19.6	-$30.6
Mississippi	-$3.7	-$6.1	-$6.1	-$12.2
Missouri	-$3.7	-$9.8	-$15.9	-$39.2
Montana	$0.0	-$1.2	-$1.2	-$1.2
Nebraska	-$2.4	-$3.7	-$4.9	-$7.3
Nevada	-$24.5	-$71.0	-$95.5	-$23.3
New Hampshire	-$1.2	-$2.4	-$2.4	-$3.7
New Jersey	-$17.1	-$29.4	-$31.8	-$45.3
New Mexico	-$14.7	-$62.4	-$24.5	-$36.7
New York	-$28.2	-$55.1	-$69.8	-$96.7
North Carolina	-$33.1	-$44.1	-$47.7	-$74.7
North Dakota	$0.0	-$1.2	-$2.4	-$2.4
Ohio	-$3.7	-$41.6	-$69.8	-$105.3
Oklahoma	-$31.8	-$82.0	-$6.1	-$45.3
Oregon	$6.1	$3.7	$13.5	$17.1
Pennsylvania	-$26.9	-$50.2	-$56.3	-$79.6
Rhode Island	-$1.2	-$1.2	-$1.2	-$1.2
South Carolina	-$17.1	-$20.8	-$23.3	-$35.5
South Dakota	$0.0	-$1.2	-$1.2	-$2.4
Tennessee	-$20.8	-$46.5	-$61.2	-$86.9
Texas	-$85.7	-$156.7	-$106.5	-$183.6
Utah	-$12.2	-$35.5	-$41.6	-$23.3
Vermont	$0.0	-$1.2	-$2.4	-$3.7
Virginia	-$25.7	-$49.0	-$51.4	-$75.9
Washington	$7.3	$0.0	$22.0	$20.8
West Virginia	-$3.7	-$74.7	-$94.3	-$134.7
Wisconsin	-$1.2	-$6.1	-$17.1	-$38.0
Wyoming	-$4.9	-$15.9	-$2.4	-$14.7

Table E-10. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Educational Services ($M)

Region	2020	2030	2040	2050
United States	-$15.9	-$93.0	-$202.0	-$345.2
Alabama	$0.0	-$1.2	-$2.4	-$3.7
Arizona	-$2.4	-$8.6	-$17.1	-$17.1
Arkansas	$0.0	$0.0	-$1.2	-$1.2
California	$2.4	-$1.2	-$6.1	$11.0
Colorado	$0.0	-$3.7	-$3.7	-$4.9
Connecticut	$0.0	-$1.2	-$2.4	-$4.9
Delaware	$0.0	$0.0	$0.0	-$1.2
District of Columbia	$0.0	-$2.4	-$3.7	-$7.3
Florida	-$4.9	-$9.8	-$15.9	-$22.0
Georgia	-$2.4	-$6.1	-$11.0	-$18.4
Idaho	$0.0	$0.0	$0.0	$0.0
Illinois	$2.4	$2.4	-$1.2	-$17.1
Indiana	$0.0	-$1.2	-$4.9	-$11.0
Iowa	$0.0	$0.0	-$1.2	-$2.4
Kansas	$0.0	$0.0	-$1.2	-$1.2
Kentucky	$0.0	-$1.2	-$3.7	-$8.6
Louisiana	$0.0	-$1.2	-$2.4	-$3.7
Maine	$0.0	$0.0	$0.0	-$1.2
Maryland	-$1.2	-$2.4	-$6.1	-$11.0
Massachusetts	$0.0	-$1.2	-$4.9	-$11.0
Michigan	$0.0	$0.0	-$2.4	-$7.3
Minnesota	$1.2	$1.2	$0.0	-$3.7
Mississippi	$0.0	$0.0	-$1.2	-$1.2
Missouri	$0.0	$0.0	-$2.4	-$7.3

Region	2020	2030	2040	2050
Montana	$0.0	$0.0	$0.0	$0.0
Nebraska	$0.0	$0.0	$0.0	-$1.2
Nevada	$0.0	-$1.2	-$3.7	-$2.4
New Hampshire	$0.0	$0.0	-$1.2	-$2.4
New Jersey	$0.0	-$2.4	-$4.9	-$8.6
New Mexico	$0.0	-$3.7	-$3.7	-$4.9
New York	-$2.4	-$9.8	-$20.8	-$36.7
North Carolina	-$1.2	-$4.9	-$8.6	-$14.7
North Dakota	$0.0	$0.0	$0.0	$0.0
Ohio	$0.0	-$2.4	-$8.6	-$18.4
Oklahoma	-$1.2	-$4.9	-$3.7	-$6.1
Oregon	$1.2	$1.2	$3.7	$4.9
Pennsylvania	-$2.4	-$8.6	-$18.4	-$35.5
Rhode Island	$0.0	$0.0	-$1.2	-$1.2
South Carolina	$0.0	-$1.2	-$2.4	-$3.7
South Dakota	$0.0	$0.0	$0.0	$0.0
Tennessee	-$1.2	-$3.7	-$8.6	-$15.9
Texas	-$3.7	-$8.6	-$12.2	-$19.6
Utah	$0.0	-$2.4	-$6.1	-$6.1
Vermont	$0.0	$0.0	-$1.2	-$1.2
Virginia	-$1.2	-$3.7	-$6.1	-$11.0
Washington	$1.2	$2.4	$3.7	$4.9
West Virginia	$0.0	-$1.2	-$2.4	-$4.9
Wisconsin	$0.0	$0.0	-$1.2	-$4.9
Wyoming	$0.0	$0.0	$0.0	$0.0

Table E-11. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Finance and Insurance ($M)

Region	2020	2030	2040	2050
United States	**-$882.7**	**-$3,500.0**	**-$6,563.0**	**-$10,085.5**
Alabama	-$9.8	-$23.3	-$36.7	-$84.9
Arizona	-$20.8	-$127.3	-$254.6	-$254.6
Arkansas	-$3.7	-$9.8	-$13.5	-$24.5
California	-$55.1	-$192.2	-$468.9	-$395.4
Colorado	-$3.7	-$106.5	-$101.6	-$142.0
Connecticut	-$31.8	-$128.5	-$235.1	-$362.4
Delaware	-$7.3	-$24.5	-$42.8	-$68.6
District of Columbia	-$4.9	-$12.2	-$22.0	-$34.3
Florida	-$80.8	-$148.1	-$217.9	-$311.0
Georgia	-$46.5	-$88.1	-$133.4	-$206.9
Idaho	$0.0	-$1.2	-$2.4	-$2.4
Illinois	-$8.6	-$71.0	-$180.0	-$433.4
Indiana	-$2.4	-$23.3	-$62.4	-$120.0
Iowa	-$1.2	-$14.7	-$26.9	-$53.9
Kansas	-$2.4	-$13.5	-$17.1	-$38.0
Kentucky	-$6.1	-$19.6	-$83.2	-$146.9
Louisiana	-$4.9	-$13.5	-$20.8	-$35.5
Maine	-$1.2	-$3.7	-$6.1	-$8.6
Maryland	-$17.1	-$51.4	-$85.7	-$132.2
Massachusetts	-$30.6	-$118.7	-$209.3	-$315.8
Michigan	-$4.9	-$23.3	-$63.7	-$112.6
Minnesota	-$6.1	-$26.9	-$57.5	-$122.4
Mississippi	-$2.4	-$6.1	-$11.0	-$19.6
Missouri	-$2.4	-$17.1	-$30.6	-$75.9
Montana	$0.0	-$2.4	-$3.7	-$4.9
Nebraska	-$3.7	-$11.0	-$17.1	-$28.2
Nevada	-$1.2	-$23.3	-$93.0	-$53.9
New Hampshire	-$2.4	-$9.8	-$15.9	-$23.3
New Jersey	-$40.4	-$142.0	-$252.2	-$378.3
New Mexico	-$2.4	-$39.2	-$36.7	-$49.0
New York	-$279.1	-$1,248.7	-$2,585.6	-$4,178.3
North Carolina	-$35.5	-$83.2	-$140.8	-$225.3
North Dakota	$0.0	-$2.4	-$3.7	-$6.1
Ohio	-$7.3	-$66.1	-$145.7	-$239.9
Oklahoma	-$3.7	-$83.2	-$31.8	-$82.0
Oregon	$4.9	$3.7	$9.8	$13.5
Pennsylvania	-$34.3	-$107.7	-$188.5	-$293.8
Rhode Island	-$1.2	-$6.1	-$9.8	-$15.9
South Carolina	-$8.6	-$19.6	-$30.6	-$50.2
South Dakota	$0.0	-$4.9	-$8.6	-$13.5
Tennessee	-$19.6	-$51.4	-$111.4	-$166.5
Texas	-$67.3	-$204.4	-$243.6	-$386.9
Utah	-$4.9	-$24.5	-$71.0	-$66.1
Vermont	$0.0	-$2.4	-$4.9	-$7.3
Virginia	-$22.0	-$64.9	-$109.0	-$170.2
Washington	$4.9	$2.4	$12.2	$14.7
West Virginia	-$1.2	-$26.9	-$57.5	-$83.2
Wisconsin	-$2.4	-$13.5	-$33.1	-$69.8
Wyoming	$0.0	-$2.4	-$4.9	-$13.5

Table E-12. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Forestry, Fishing, Related Activities, and Other ($M)

Region	2020	2030	2040	2050
United States	-$16.9	-$31.8	-$31.8	-$29.4
Alabama	-$1.2	-$1.2	-$1.2	-$1.2
Arizona	$0.0	-$1.2	-$1.2	-$1.2
Arkansas	$0.0	-$1.2	-$1.2	-$1.2
California	-$2.4	-$4.9	-$7.3	-$1.2
Colorado	$0.0	$0.0	$0.0	$0.0
Connecticut	$0.0	$0.0	$0.0	$0.0
Delaware	$0.0	$0.0	$0.0	$0.0
District of Columbia	$1.2	$1.2	$1.2	$1.2
Florida	-$3.7	-$4.9	-$6.1	-$8.6
Georgia	-$2.4	-$3.7	-$2.4	-$2.4
Idaho	$0.0	$0.0	$0.0	$0.0
Illinois	$0.0	$0.0	$0.0	$0.0
Indiana	$0.0	$0.0	$0.0	$0.0
Iowa	$0.0	$0.0	$0.0	$0.0
Kansas	$0.0	$0.0	$0.0	$0.0
Kentucky	$0.0	$0.0	-$1.2	-$1.2
Louisiana	-$1.2	-$1.2	-$1.2	-$1.2
Maine	$0.0	-$1.2	$0.0	$0.0
Maryland	$0.0	$0.0	$0.0	$0.0
Massachusetts	$0.0	-$1.2	$0.0	$0.0
Michigan	$0.0	$0.0	$0.0	$0.0
Minnesota	$0.0	$0.0	$0.0	$0.0
Mississippi	$0.0	-$1.2	-$1.2	-$1.2
Missouri	$0.0	$0.0	$0.0	$0.0
Montana	$0.0	$0.0	$0.0	$0.0
Nebraska	$0.0	$0.0	$0.0	$0.0
Nevada	$0.0	$0.0	$0.0	$0.0
New Hampshire	$0.0	$0.0	$0.0	$0.0
New Jersey	$0.0	$0.0	$0.0	$0.0
New Mexico	$0.0	$0.0	$0.0	$0.0
New York	-$1.2	-$1.2	-$2.4	-$3.7
North Carolina	-$1.2	-$1.2	-$1.2	-$1.2
North Dakota	$0.0	$0.0	$0.0	$0.0
Ohio	$0.0	$0.0	$0.0	$0.0
Oklahoma	$0.0	$0.0	$0.0	-$1.2
Oregon	$0.0	-$1.2	$0.0	$1.2
Pennsylvania	$0.0	-$1.2	-$1.2	-$1.2
Rhode Island	$0.0	$0.0	$0.0	$0.0
South Carolina	-$1.2	-$1.2	-$1.2	-$1.2
South Dakota	$0.0	$0.0	$0.0	$0.0
Tennessee	$0.0	$0.0	$0.0	-$1.2
Texas	-$2.4	-$3.7	-$3.7	-$4.9
Utah	$0.0	$0.0	$0.0	$0.0
Vermont	$0.0	$0.0	$0.0	$0.0
Virginia	$0.0	-$1.2	-$1.2	-$1.2
Washington	$0.0	$0.0	$1.2	$2.4
West Virginia	$0.0	$0.0	$0.0	$1.2
Wisconsin	$0.0	$0.0	$0.0	$0.0
Wyoming	$0.0	$0.0	$0.0	$0.0

Table E-13. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Health Care and Social Assistance ($M)

Region	2020	2030	2040	2050
United States	**-$530.1**	**-$2,648.8**	**-$6,187.2**	**-$13,029.4**
Alabama	-$11.0	-$35.5	-$82.0	-$198.3
Arizona	-$25.7	-$171.4	-$457.9	-$632.9
Arkansas	-$4.9	-$20.8	-$41.6	-$102.8
California	-$25.7	-$118.7	-$400.3	-$449.3
Colorado	-$4.9	-$110.2	-$138.3	-$271.8
Connecticut	-$6.1	-$24.5	-$56.3	-$113.9
Delaware	-$2.4	-$7.3	-$15.9	-$33.1
District of Columbia	-$1.2	-$4.9	-$12.2	-$29.4
Florida	-$79.6	-$189.8	-$396.6	-$750.4
Georgia	-$44.1	-$104.1	-$216.7	-$457.9
Idaho	$1.2	$0.0	-$1.2	-$2.4
Illinois	$4.9	-$12.2	-$97.9	-$461.5
Indiana	-$1.2	-$44.1	-$184.9	-$510.5
Iowa	$2.4	-$7.3	-$30.6	-$100.4
Kansas	-$3.7	-$18.4	-$35.5	-$111.4
Kentucky	-$7.3	-$35.5	-$225.3	-$602.3
Louisiana	-$7.3	-$29.4	-$61.2	-$149.4
Maine	-$1.2	-$4.9	-$12.2	-$22.0
Maryland	-$13.5	-$46.5	-$102.8	-$222.8
Massachusetts	-$7.3	-$36.7	-$84.5	-$176.3
Michigan	-$4.9	-$33.1	-$139.6	-$352.6
Minnesota	-$1.2	-$24.5	-$85.7	-$249.7
Mississippi	-$2.4	-$12.2	-$31.8	-$77.1
Missouri	-$1.2	-$14.7	-$46.5	-$184.9

Region	2020	2030	2040	2050
Montana	$0.0	-$1.2	-$6.1	-$13.5
Nebraska	-$2.4	-$11.0	-$30.6	-$68.6
Nevada	-$4.9	-$44.1	-$210.6	-$183.6
New Hampshire	-$1.2	-$7.3	-$18.4	-$39.2
New Jersey	-$23.3	-$75.9	-$162.8	-$329.3
New Mexico	-$9.8	-$115.1	-$151.8	-$277.9
New York	-$44.1	-$155.5	-$363.6	-$749.2
North Carolina	-$29.4	-$77.1	-$173.8	-$373.4
North Dakota	$0.0	-$3.7	-$9.8	-$22.0
Ohio	-$6.1	-$96.7	-$308.5	-$714.9
Oklahoma	-$14.7	-$183.6	-$113.9	-$361.1
Oregon	$8.6	$12.2	$33.1	$58.8
Pennsylvania	-$33.1	-$123.6	-$292.6	-$618.2
Rhode Island	-$1.2	-$4.9	-$11.0	-$20.8
South Carolina	-$11.0	-$28.2	-$61.2	-$134.7
South Dakota	$0.0	-$3.7	-$8.6	-$22.0
Tennessee	-$23.3	-$82.0	-$263.2	-$549.7
Texas	-$62.4	-$225.3	-$406.4	-$864.3
Utah	-$7.3	-$34.3	-$138.3	-$177.5
Vermont	-$1.2	-$3.7	-$12.2	-$25.7
Virginia	-$18.4	-$66.1	-$150.6	-$322.0
Washington	$8.6	$11.0	$34.3	$51.4
West Virginia	-$2.4	-$100.4	-$312.2	-$700.3
Wisconsin	-$1.2	-$14.7	-$68.6	-$224.0
Wyoming	-$1.2	-$7.3	-$15.9	-$68.6

Table E-14. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Information ($M)

Region	2020	2030	2040	2050
United States	-$544.8	-$2,152.2	-$4,409.6	-$7,957.4
Alabama	-$6.1	-$18.4	-$39.2	-$80.8
Arizona	-$17.1	-$88.1	-$194.7	-$253.4
Arkansas	-$2.4	-$9.8	-$20.8	-$42.8
California	-$68.6	-$328.1	-$793.3	-$1,005.1
Colorado	-$17.1	-$132.2	-$180.0	-$311.0
Connecticut	-$4.9	-$18.4	-$36.7	-$71.0
Delaware	-$1.2	-$3.7	-$7.3	-$13.5
District of Columbia	-$4.9	-$18.4	-$35.5	-$69.8
Florida	-$66.1	-$142.0	-$248.5	-$417.5
Georgia	-$53.9	-$131.0	-$251.0	-$466.4
Idaho	$0.0	-$2.4	-$3.7	-$4.9
Illinois	$2.4	-$14.7	-$80.8	-$271.8
Indiana	-$1.2	-$13.5	-$51.4	-$129.8
Iowa	$1.2	-$6.1	-$22.0	-$57.5
Kansas	-$4.9	-$26.9	-$50.2	-$111.4
Kentucky	-$3.7	-$13.5	-$53.9	-$128.5
Louisiana	-$3.7	-$12.2	-$24.5	-$51.4
Maine	$0.0	-$2.4	-$4.9	-$11.0
Maryland	-$9.8	-$34.3	-$68.6	-$134.7
Massachusetts	-$9.8	-$39.2	-$80.8	-$175.1
Michigan	-$2.4	-$17.1	-$58.8	-$140.8
Minnesota	$1.2	-$12.2	-$40.4	-$110.2
Mississippi	-$1.2	-$6.1	-$12.2	-$25.7
Missouri	-$3.7	-$20.8	-$51.4	-$131.0

Region	2020	2030	2040	2050
Montana	$0.0	-$2.4	-$4.9	-$9.8
Nebraska	$1.2	-$7.3	-$15.9	-$35.5
Nevada	-$3.7	-$20.8	-$67.3	-$56.3
New Hampshire	-$1.2	-$4.9	-$9.8	-$22.0
New Jersey	-$22.0	-$72.2	-$140.8	-$265.7
New Mexico	-$4.9	-$38.0	-$49.0	-$80.8
New York	-$58.8	-$195.9	-$404.0	-$771.3
North Carolina	-$20.8	-$53.9	-$104.1	-$202.0
North Dakota	$0.0	-$2.4	-$6.1	-$13.5
Ohio	-$3.7	-$41.6	-$120.0	-$268.1
Oklahoma	-$12.2	-$64.9	-$53.9	-$120.0
Oregon	$3.7	$2.4	$8.6	$24.5
Pennsylvania	-$19.6	-$66.1	-$134.7	-$260.8
Rhode Island	-$1.2	-$3.7	-$7.3	-$14.7
South Carolina	-$6.1	-$17.1	-$34.3	-$67.3
South Dakota	$0.0	-$2.4	-$4.9	-$11.0
Tennessee	-$11.0	-$36.7	-$94.3	-$192.2
Texas	-$62.4	-$214.2	-$334.2	-$624.4
Utah	-$7.3	-$31.8	-$84.5	-$111.4
Vermont	$0.0	-$2.4	-$4.9	-$9.8
Virginia	-$25.7	-$85.7	-$171.4	-$323.2
Washington	-$9.8	-$52.6	-$82.0	-$112.6
West Virginia	-$1.2	-$15.9	-$41.6	-$90.6
Wisconsin	$0.0	-$7.3	-$29.4	-$83.2
Wyoming	$0.0	-$2.4	-$6.1	-$14.7

Table E-15. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Management of Companies and Enterprises ($M)

Region	2020	2030	2040	2050
United States	**-$231.4**	**-$744.3**	**-$1,033.2**	**-$1,051.6**
Alabama	-$3.7	-$6.1	-$7.3	-$8.6
Arizona	-$4.9	-$34.3	-$56.3	-$44.1
Arkansas	-$3.7	-$13.5	-$12.2	-$14.7
California	-$14.7	-$51.4	-$89.4	-$19.6
Colorado	$0.0	-$28.2	-$24.5	-$25.7
Connecticut	-$3.7	-$11.0	-$13.5	-$13.5
Delaware	-$2.4	-$4.9	-$6.1	-$6.1
District of Columbia	$0.0	-$1.2	-$1.2	-$1.2
Florida	-$31.8	-$47.7	-$52.6	-$50.2
Georgia	-$28.2	-$41.6	-$46.5	-$46.5
Idaho	$1.2	$0.0	-$1.2	$0.0
Illinois	$2.4	-$6.1	-$24.5	-$50.2
Indiana	$0.0	-$6.1	-$14.7	-$20.8
Iowa	$0.0	$0.0	-$2.4	-$3.7
Kansas	$0.0	-$2.4	-$2.4	-$3.7
Kentucky	-$3.7	-$7.3	-$24.5	-$31.8
Louisiana	-$1.2	-$4.9	-$6.1	-$8.6
Maine	$0.0	$0.0	$0.0	$0.0
Maryland	-$2.4	-$7.3	-$8.6	-$9.8
Massachusetts	-$1.2	-$8.6	-$11.0	-$14.7
Michigan	-$1.2	-$11.0	-$24.5	-$30.6
Minnesota	-$2.4	-$15.9	-$24.5	-$38.0
Mississippi	-$1.2	-$2.4	-$2.4	-$3.7
Missouri	-$2.4	-$14.7	-$20.8	-$31.8
Montana	$0.0	$0.0	$0.0	$0.0
Nebraska	-$1.2	-$3.7	-$4.9	-$6.1
Nevada	-$1.2	-$22.0	-$64.9	-$30.6
New Hampshire	$0.0	-$2.4	-$2.4	-$3.7
New Jersey	-$12.2	-$31.8	-$36.7	-$38.0
New Mexico	-$1.2	-$13.5	-$11.0	-$11.0
New York	-$29.4	-$72.2	-$88.1	-$93.0
North Carolina	-$22.0	-$39.2	-$47.7	-$52.6
North Dakota	$0.0	-$1.2	-$1.2	-$1.2
Ohio	-$4.9	-$38.0	-$68.6	-$84.5
Oklahoma	-$3.7	-$29.4	-$12.2	-$18.4
Oregon	$6.1	$6.1	$11.0	$13.5
Pennsylvania	-$19.6	-$52.6	-$67.3	-$72.2
Rhode Island	$0.0	-$2.4	-$2.4	-$2.4
South Carolina	-$3.7	-$6.1	-$7.3	-$7.3
South Dakota	$0.0	$0.0	-$1.2	-$1.2
Tennessee	-$6.1	-$12.2	-$19.6	-$20.8
Texas	-$13.5	-$35.5	-$39.2	-$46.5
Utah	-$1.2	-$9.8	-$23.3	-$15.9
Vermont	$0.0	$0.0	$0.0	$0.0
Virginia	-$18.4	-$45.3	-$56.3	-$61.2
Washington	$6.1	$7.3	$14.7	$17.1
West Virginia	$0.0	-$9.8	-$18.4	-$22.0
Wisconsin	$0.0	-$2.4	-$8.6	-$14.7
Wyoming	$0.0	-$1.2	-$1.2	-$2.4

Table E-16. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Manufacturing ($M)

Region	2020	2030	2040	2050
United States	**-$1,878.0**	**-$6,584.9**	**-$11,671.3**	**-$20,786.0**
Alabama	-$73.5	-$178.7	-$385.6	-$916.9
Arizona	-$47.7	-$199.5	-$385.6	-$548.5
Arkansas	-$30.6	-$63.7	-$180.0	-$488.5
California	-$167.7	-$771.3	-$1,854.7	-$379.5
Colorado	$28.2	-$6.1	$45.3	$79.6
Connecticut	$7.3	$4.9	$8.6	$18.4
Delaware	-$8.6	-$22.0	-$36.7	-$72.2
District of Columbia	$0.0	$0.0	$0.0	$0.0
Florida	-$286.5	-$549.7	-$937.8	-$1,662.5
Georgia	-$306.1	-$592.5	-$1,068.7	-$2,206.0
Idaho	$11.0	$18.4	$62.4	$132.2
Illinois	$68.6	$140.8	-$31.8	-$422.4
Indiana	$12.2	-$34.3	-$277.9	-$630.5
Iowa	$15.9	$45.3	-$33.1	-$140.8
Kansas	-$9.8	-$30.6	-$80.8	-$159.1
Kentucky	-$67.3	-$160.4	-$391.8	-$913.3
Louisiana	-$17.1	-$61.2	-$109.0	-$285.2
Maine	$6.1	$11.0	$18.4	$36.7
Maryland	-$23.3	-$58.8	-$101.6	-$216.7
Massachusetts	$22.0	$29.4	$68.6	$120.0
Michigan	-$2.4	-$63.7	-$290.1	-$700.3
Minnesota	$6.1	$9.8	-$68.6	-$231.4
Mississippi	-$4.9	-$26.9	-$71.0	-$215.5
Missouri	$31.8	$49.0	$11.0	-$74.7

Region	2020	2030	2040	2050
Montana	$6.1	$9.8	$23.3	$45.3
Nebraska	-$4.9	-$3.7	-$36.7	-$85.7
Nevada	-$2.4	-$15.9	-$56.3	-$35.5
New Hampshire	$3.7	$2.4	$3.7	$1.2
New Jersey	-$40.4	-$120.0	-$204.4	-$401.5
New Mexico	-$8.6	-$52.6	-$77.1	-$116.3
New York	-$126.1	-$303.6	-$544.8	-$974.5
North Carolina	-$219.1	-$446.8	-$784.7	-$1,557.2
North Dakota	-$1.2	-$2.4	-$8.6	-$19.6
Ohio	$30.6	-$96.7	-$302.4	-$717.4
Oklahoma	-$58.8	-$176.3	-$299.9	-$614.6
Oregon	$53.9	$86.9	$232.6	$446.8
Pennsylvania	-$155.5	-$417.5	-$739.4	-$1,385.8
Rhode Island	$1.2	$2.4	$6.1	$14.7
South Carolina	-$69.8	-$146.9	-$262.0	-$554.6
South Dakota	$0.0	-$2.4	-$8.6	-$26.9
Tennessee	-$129.8	-$323.2	-$689.2	-$1,433.6
Texas	-$284.0	-$893.7	-$1,393.2	-$2,725.1
Utah	-$13.5	-$63.7	-$154.3	-$228.9
Vermont	$3.7	$4.9	$3.7	$8.6
Virginia	-$110.2	-$243.6	-$390.5	-$756.6
Washington	$75.9	$131.0	$369.7	$673.3
West Virginia	-$9.8	-$44.1	-$100.4	-$183.6
Wisconsin	$7.3	$20.8	-$107.7	-$358.7
Wyoming	$0.0	-$2.4	-$3.7	-$9.8

Table E-17. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Mining ($M)

Region	2020	2030	2040	2050
United States	-$126.1	-$5,106.2	-$11,485.6	-$19,774.8
Alabama	-$1.2	-$11.0	-$33.1	-$66.1
Arizona	-$3.7	-$606.0	-$1,436.0	-$1,265.8
Arkansas	-$1.2	-$4.9	-$13.5	-$39.2
California	$1.2	-$20.8	-$55.1	-$78.4
Colorado	-$4.9	-$362.4	-$421.1	-$648.8
Connecticut	$0.0	-$1.2	-$2.4	-$4.9
Delaware	$0.0	$0.0	$0.0	$0.0
District of Columbia	$0.0	$0.0	$0.0	-$1.2
Florida	-$1.2	-$3.7	-$12.2	-$23.3
Georgia	-$1.2	-$9.8	-$30.6	-$58.8
Idaho	$0.0	-$3.7	-$12.2	-$18.4
Illinois	-$1.2	-$11.0	-$66.1	-$880.2
Indiana	-$1.2	-$148.1	-$494.6	-$1,145.9
Iowa	$0.0	-$23.3	-$40.4	-$194.7
Kansas	-$1.2	-$11.0	-$31.8	-$140.8
Kentucky	-$4.9	-$38.0	-$1,056.5	-$2,453.3
Louisiana	-$7.3	-$42.8	-$97.9	-$217.9
Maine	$0.0	$0.0	$0.0	$0.0
Maryland	$0.0	-$2.4	-$6.1	-$12.2
Massachusetts	$0.0	-$1.2	-$3.7	-$7.3
Michigan	-$1.2	-$7.3	-$151.8	-$331.8
Minnesota	-$1.2	-$7.3	-$95.5	-$395.4
Mississippi	-$1.2	-$4.9	-$12.2	-$25.7
Missouri	-$1.2	-$7.3	-$23.3	-$293.8
Montana	-$1.2	-$11.0	-$35.5	-$58.8
Nebraska	-$2.4	-$3.7	-$13.5	-$25.7
Nevada	-$3.7	-$326.9	-$1,722.5	-$1,063.8
New Hampshire	$0.0	$0.0	-$1.2	-$3.7
New Jersey	$0.0	-$1.2	-$4.9	-$8.6
New Mexico	-$30.6	-$572.9	-$547.2	-$707.6
New York	$0.0	-$3.7	-$12.2	-$23.3
North Carolina	-$1.2	-$6.1	-$19.6	-$39.2
North Dakota	-$1.2	-$6.1	-$15.9	-$31.8
Ohio	-$1.2	-$157.9	-$471.3	-$859.4
Oklahoma	-$6.1	-$1,068.7	-$260.8	-$929.2
Oregon	$0.0	-$2.4	-$7.3	-$9.8
Pennsylvania	-$2.4	-$26.9	-$82.0	-$161.6
Rhode Island	$0.0	$0.0	-$1.2	-$1.2
South Carolina	$0.0	-$1.2	-$4.9	-$9.8
South Dakota	$0.0	-$1.2	-$2.4	-$6.1
Tennessee	$0.0	-$35.5	-$280.3	-$394.2
Texas	-$28.2	-$216.7	-$346.5	-$726.0
Utah	-$2.4	-$57.5	-$399.1	-$331.8
Vermont	$0.0	-$8.6	-$34.3	-$56.3
Virginia	-$1.2	-$13.5	-$41.6	-$83.2
Washington	$0.0	-$4.9	-$15.9	-$23.3
West Virginia	-$4.9	-$1,193.6	-$2,880.6	-$5,167.4
Wisconsin	$0.0	-$3.7	-$42.8	-$221.6
Wyoming	-$4.9	-$39.2	-$107.7	-$455.4

Table E-18. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Other Services, except Public Administration ($M)

Region	2020	2030	2040	2050
United States	**-$178.7**	**-$711.3**	**-$1,500.9**	**-$2,771.6**
Alabama	-$4.9	-$11.0	-$22.0	-$45.3
Arizona	-$8.6	-$41.6	-$91.8	-$110.2
Arkansas	-$1.2	-$4.9	-$8.6	-$19.6
California	-$9.8	-$44.1	-$129.8	-$120.0
Colorado	-$2.4	-$31.8	-$34.3	-$60.0
Connecticut	-$1.2	-$6.1	-$12.2	-$23.3
Delaware	-$1.2	-$2.4	-$3.7	-$7.3
District of Columbia	-$1.2	-$4.9	-$9.8	-$18.4
Florida	-$29.4	-$58.8	-$101.6	-$171.4
Georgia	-$18.4	-$35.5	-$61.2	-$111.4
Idaho	$0.0	$0.0	$0.0	$1.2
Illinois	$2.4	-$3.7	-$31.8	-$116.3
Indiana	$0.0	-$11.0	-$42.8	-$102.8
Iowa	$2.4	$0.0	-$7.3	-$22.0
Kansas	-$1.2	-$4.9	-$8.6	-$22.0
Kentucky	-$2.4	-$8.6	-$46.5	-$110.2
Louisiana	-$2.4	-$8.6	-$15.9	-$36.7
Maine	$0.0	$0.0	-$1.2	-$2.4
Maryland	-$4.9	-$15.9	-$31.8	-$60.0
Massachusetts	-$1.2	-$7.3	-$17.1	-$36.7
Michigan	-$1.2	-$8.6	-$31.8	-$71.0
Minnesota	$1.2	-$4.9	-$17.1	-$46.5
Mississippi	-$1.2	-$2.4	-$7.3	-$15.9
Missouri	$0.0	-$4.9	-$14.7	-$46.5

Region	2020	2030	2040	2050
Montana	$0.0	$0.0	-$1.2	-$2.4
Nebraska	$1.2	-$2.4	-$6.1	-$13.5
Nevada	-$2.4	-$13.5	-$51.4	-$38.0
New Hampshire	$0.0	-$1.2	-$3.7	-$7.3
New Jersey	-$7.3	-$19.6	-$38.0	-$68.6
New Mexico	-$3.7	-$26.9	-$29.4	-$46.5
New York	-$13.5	-$41.6	-$86.9	-$157.9
North Carolina	-$9.8	-$20.8	-$39.2	-$75.9
North Dakota	$0.0	-$1.2	-$2.4	-$4.9
Ohio	-$1.2	-$25.7	-$74.7	-$156.7
Oklahoma	-$6.1	-$46.5	-$25.7	-$72.2
Oregon	$3.7	$4.9	$9.8	$14.7
Pennsylvania	-$9.8	-$29.4	-$58.8	-$111.4
Rhode Island	$0.0	-$1.2	-$2.4	-$3.7
South Carolina	-$4.9	-$9.8	-$18.4	-$35.5
South Dakota	$1.2	$0.0	-$1.2	-$3.7
Tennessee	-$7.3	-$22.0	-$60.0	-$112.6
Texas	-$23.3	-$69.8	-$106.5	-$200.8
Utah	-$2.4	-$12.2	-$35.5	-$40.4
Vermont	$0.0	$0.0	-$1.2	-$3.7
Virginia	-$8.6	-$25.7	-$49.0	-$91.8
Washington	$3.7	$4.9	$12.2	$17.1
West Virginia	-$1.2	-$24.5	-$63.7	-$123.6
Wisconsin	$0.0	-$2.4	-$13.5	-$39.2
Wyoming	$0.0	-$2.4	-$4.9	-$15.9

Table E-19. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Professional and Technical Services ($M)

Region	2020	2030	2040	2050
United States	**-$581.5**	**-$2,062.8**	**-$3,187.9**	**-$4,421.9**
Alabama	-$11.0	-$24.5	-$36.7	-$57.5
Arizona	-$24.5	-$106.5	-$178.7	-$175.1
Arkansas	-$2.4	-$6.1	-$8.6	-$14.7
California	-$45.3	-$206.9	-$382.0	-$254.6
Colorado	-$12.2	-$106.5	-$91.8	-$124.9
Connecticut	-$4.9	-$18.4	-$28.2	-$42.8
Delaware	-$2.4	-$7.3	-$11.0	-$17.1
District of Columbia	-$12.2	-$39.2	-$62.4	-$97.9
Florida	-$88.1	-$150.6	-$195.9	-$255.9
Georgia	-$50.2	-$86.9	-$117.5	-$164.0
Idaho	$0.0	-$2.4	-$2.4	-$2.4
Illinois	$9.8	-$18.4	-$91.8	-$235.1
Indiana	$0.0	-$12.2	-$38.0	-$69.8
Iowa	$4.9	$1.2	-$4.9	-$13.5
Kansas	-$1.2	-$8.6	-$11.0	-$22.0
Kentucky	-$3.7	-$12.2	-$46.5	-$83.2
Louisiana	-$3.7	-$13.5	-$17.1	-$28.2
Maine	$0.0	-$1.2	-$2.4	-$3.7
Maryland	-$20.8	-$63.7	-$99.2	-$155.5
Massachusetts	-$11.0	-$46.5	-$73.5	-$122.4
Michigan	-$3.7	-$31.8	-$82.0	-$145.7
Minnesota	$7.3	-$4.9	-$25.7	-$60.0
Mississippi	-$1.2	-$3.7	-$6.1	-$11.0
Missouri	$0.0	-$8.6	-$19.6	-$49.0
Montana	$0.0	-$1.2	-$1.2	-$2.4
Nebraska	$4.9	-$2.4	-$6.1	-$11.0
Nevada	-$8.6	-$40.4	-$102.8	-$61.2
New Hampshire	-$1.2	-$3.7	-$6.1	-$11.0
New Jersey	-$26.9	-$79.6	-$121.2	-$180.0
New Mexico	-$12.2	-$77.1	-$67.3	-$78.4
New York	-$60.0	-$182.4	-$299.9	-$446.8
North Carolina	-$23.3	-$45.3	-$64.9	-$95.5
North Dakota	$1.2	-$1.2	-$1.2	-$2.4
Ohio	-$1.2	-$45.3	-$99.2	-$164.0
Oklahoma	-$14.7	-$88.1	-$38.0	-$68.6
Oregon	$6.1	$7.3	$14.7	$19.6
Pennsylvania	-$31.8	-$89.4	-$135.9	-$199.5
Rhode Island	$0.0	-$2.4	-$3.7	-$4.9
South Carolina	-$8.6	-$15.9	-$22.0	-$33.1
South Dakota	$1.2	$0.0	-$1.2	-$1.2
Tennessee	-$14.7	-$38.0	-$72.2	-$105.3
Texas	-$74.7	-$199.5	-$225.3	-$328.1
Utah	-$7.3	-$26.9	-$58.8	-$55.1
Vermont	$0.0	-$2.4	-$3.7	-$6.1
Virginia	-$40.4	-$121.2	-$186.1	-$282.8
Washington	$8.6	$7.3	$22.0	$29.4
West Virginia	-$1.2	-$29.4	-$53.9	-$79.6
Wisconsin	$1.2	-$2.4	-$14.7	-$35.5
Wyoming	-$1.2	-$3.7	-$4.9	-$11.0

Table E-20. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Real Estate and Rental and Leasing ($M)

Region	2020	2030	2040	2050
United States	**-$630.1**	**-$2,504.8**	**-$3,886.9**	**-$6,048.9**
Alabama	-$12.2	-$25.7	-$40.4	-$78.4
Arizona	-$62.4	-$266.9	-$441.9	-$422.4
Arkansas	-$3.7	-$12.2	-$15.9	-$31.8
California	$31.8	-$61.2	-$156.7	$400.3
Colorado	-$12.2	-$170.2	-$115.1	-$157.9
Connecticut	$0.0	-$7.3	-$13.5	-$28.2
Delaware	-$2.4	-$6.1	-$9.8	-$19.6
District of Columbia	-$6.1	-$22.0	-$47.7	-$97.9
Florida	-$153.0	-$303.6	-$448.1	-$751.7
Georgia	-$75.9	-$144.5	-$231.4	-$411.3
Idaho	$2.4	$2.4	$4.9	$12.2
Illinois	$29.4	$23.3	-$77.1	-$386.0
Indiana	$4.9	-$18.4	-$82.0	-$187.3
Iowa	$4.9	$2.4	-$7.3	-$26.9
Kansas	-$1.2	-$9.8	-$9.8	-$30.6
Kentucky	-$4.9	-$17.1	-$85.7	-$166.5
Louisiana	-$6.1	-$26.9	-$24.5	-$46.5
Maine	$1.2	$1.2	$1.2	$0.0
Maryland	-$15.9	-$61.2	-$117.5	-$243.6
Massachusetts	$7.3	$4.9	$1.2	-$19.6
Michigan	$6.1	$1.2	-$40.4	-$111.4
Minnesota	$11.0	$7.3	-$20.8	-$86.9
Mississippi	-$1.2	-$6.1	-$9.8	-$20.8
Missouri	$3.7	-$2.4	-$14.7	-$73.5
Montana	$1.2	$0.0	-$1.2	-$1.2
Nebraska	$1.2	-$2.4	-$7.3	-$15.9
Nevada	-$18.4	-$93.0	-$247.3	-$124.9
New Hampshire	$1.2	$0.0	$0.0	-$3.7
New Jersey	-$12.2	-$44.1	-$80.8	-$151.8
New Mexico	-$15.9	-$112.6	-$79.6	-$96.7
New York	-$19.6	-$120.0	-$279.1	-$565.6
North Carolina	-$39.2	-$77.1	-$122.4	-$224.0
North Dakota	$0.0	-$1.2	-$2.4	-$3.7
Ohio	$6.1	-$55.1	-$145.7	-$301.2
Oklahoma	-$19.6	-$286.5	-$63.7	-$154.3
Oregon	$18.4	$29.4	$57.5	$99.2
Pennsylvania	-$22.0	-$63.7	-$107.7	-$194.7
Rhode Island	$1.2	$1.2	$1.2	-$1.2
South Carolina	-$19.6	-$39.2	-$61.2	-$115.1
South Dakota	$1.2	$0.0	-$1.2	-$3.7
Tennessee	-$24.5	-$64.9	-$139.6	-$230.2
Texas	-$116.3	-$333.0	-$359.9	-$615.8
Utah	-$11.0	-$44.1	-$100.4	-$90.6
Vermont	$0.0	-$1.2	-$2.4	-$4.9
Virginia	-$26.9	-$83.2	-$145.7	-$284.0
Washington	$30.6	$50.2	$104.1	$178.7
West Virginia	-$1.2	-$57.5	-$101.6	-$132.2
Wisconsin	$4.9	$7.3	-$8.6	-$47.7
Wyoming	-$1.2	-$7.3	-$7.3	-$24.5

Table E-21. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Retail Trade ($M)

Region	2020	2030	2040	2050
United States	**-$1,223.0**	**-$3,879.6**	**-$8,744.6**	**-$17,330.1**
Alabama	-$25.7	-$61.2	-$133.4	-$314.6
Arizona	-$56.3	-$279.1	-$690.5	-$945.1
Arkansas	-$9.8	-$25.7	-$53.9	-$134.7
California	-$64.9	-$198.3	-$797.0	-$244.8
Colorado	-$12.2	-$132.2	-$150.6	-$292.6
Connecticut	-$12.2	-$30.6	-$57.5	-$112.6
Delaware	-$4.9	-$12.2	-$23.3	-$47.7
District of Columbia	-$1.2	-$2.4	-$6.1	-$13.5
Florida	-$184.9	-$390.5	-$760.2	-$1,376.0
Georgia	-$96.7	-$203.2	-$407.7	-$830.0
Idaho	$1.2	$0.0	$4.9	$20.8
Illinois	$0.0	-$8.6	-$111.4	-$591.3
Indiana	-$6.1	-$50.2	-$222.8	-$653.7
Iowa	-$3.7	-$11.0	-$44.1	-$146.9
Kansas	-$9.8	-$25.7	-$47.7	-$139.6
Kentucky	-$15.9	-$52.6	-$282.8	-$814.1
Louisiana	-$15.9	-$45.3	-$86.9	-$210.6
Maine	-$2.4	-$7.3	-$14.7	-$28.2
Maryland	-$28.2	-$69.8	-$133.4	-$290.1
Massachusetts	-$11.0	-$29.4	-$55.1	-$122.4
Michigan	-$12.2	-$38.0	-$162.8	-$453.0
Minnesota	-$7.3	-$14.7	-$67.3	-$221.6
Mississippi	-$8.6	-$22.0	-$52.6	-$126.1
Missouri	-$7.3	-$22.0	-$61.2	-$236.3
Montana	$0.0	-$2.4	-$6.1	-$14.7
Nebraska	-$8.6	-$15.9	-$36.7	-$82.0
Nevada	-$20.8	-$104.1	-$363.6	-$313.4
New Hampshire	-$3.7	-$9.8	-$20.8	-$46.5
New Jersey	-$47.7	-$110.2	-$204.4	-$408.4
New Mexico	-$22.0	-$160.4	-$208.1	-$370.9
New York	-$88.1	-$213.0	-$427.3	-$852.1
North Carolina	-$62.4	-$134.7	-$273.0	-$577.8
North Dakota	-$2.4	-$6.1	-$13.5	-$30.6
Ohio	-$14.7	-$106.5	-$335.4	-$845.9
Oklahoma	-$41.6	-$235.1	-$176.3	-$487.2
Oregon	$14.7	$28.2	$78.4	$170.2
Pennsylvania	-$62.4	-$153.0	-$307.3	-$652.5
Rhode Island	-$1.2	-$3.7	-$6.1	-$12.2
South Carolina	-$30.6	-$67.3	-$139.6	-$291.4
South Dakota	-$2.4	-$4.9	-$11.0	-$28.2
Tennessee	-$44.1	-$131.0	-$368.5	-$795.7
Texas	-$132.2	-$401.5	-$652.5	-$1,365.0
Utah	-$15.9	-$68.6	-$222.8	-$299.9
Vermont	-$2.4	-$6.1	-$14.7	-$31.8
Virginia	-$44.1	-$113.9	-$227.7	-$489.7
Washington	$20.8	$38.0	$126.1	$242.4
West Virginia	-$6.1	-$140.8	-$424.8	-$1,067.5
Wisconsin	-$4.9	-$9.8	-$62.4	-$227.7
Wyoming	-$4.9	-$18.4	-$33.1	-$134.7

Table E-22. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Transportation and Warehousing ($M)

Region	2020	2030	2040	2050
United States	-$309.7	-$1,248.7	-$2,536.6	-$4,004.4
Alabama	-$6.1	-$19.6	-$36.7	-$64.9
Arizona	-$9.8	-$66.1	-$143.2	-$149.4
Arkansas	-$4.9	-$19.6	-$36.7	-$84.9
California	-$15.9	-$74.7	-$177.5	-$105.3
Colorado	-$2.4	-$36.7	-$49.0	-$73.5
Connecticut	-$1.2	-$6.1	-$11.0	-$18.4
Delaware	-$1.2	-$2.4	-$4.9	-$7.3
District of Columbia	$0.0	-$1.2	-$2.4	-$4.9
Florida	-$34.3	-$72.2	-$118.7	-$178.7
Georgia	-$31.8	-$72.2	-$123.6	-$197.1
Idaho	$0.0	-$3.7	-$8.6	-$8.6
Illinois	-$2.4	-$30.6	-$93.0	-$225.3
Indiana	-$4.9	-$28.2	-$77.1	-$153.0
Iowa	-$1.2	-$11.0	-$28.2	-$55.1
Kansas	-$2.4	-$13.5	-$25.7	-$47.7
Kentucky	-$7.3	-$31.8	-$96.7	-$187.3
Louisiana	-$3.7	-$14.7	-$26.9	-$46.5
Maine	$0.0	-$2.4	-$3.7	-$7.3
Maryland	-$4.9	-$15.9	-$30.6	-$51.4
Massachusetts	-$1.2	-$7.3	-$14.7	-$25.7
Michigan	-$3.7	-$19.6	-$52.6	-$100.4
Minnesota	-$1.2	-$12.2	-$33.1	-$69.8
Mississippi	-$3.7	-$11.0	-$20.8	-$36.7
Missouri	-$3.7	-$20.8	-$45.3	-$94.3
Montana	$0.0	-$3.7	-$9.8	-$12.2
Nebraska	-$2.4	-$17.1	-$39.2	-$67.3
Nevada	-$2.4	-$19.6	-$69.8	-$47.7
New Hampshire	$0.0	-$1.2	-$2.4	-$4.9
New Jersey	-$13.5	-$36.7	-$64.9	-$104.1
New Mexico	-$2.4	-$20.8	-$30.6	-$41.6
New York	-$15.9	-$51.4	-$94.3	-$154.3
North Carolina	-$14.7	-$39.2	-$72.2	-$121.2
North Dakota	$0.0	-$2.4	-$7.3	-$12.2
Ohio	-$8.6	-$52.6	-$128.5	-$236.3
Oklahoma	-$4.9	-$34.3	-$35.5	-$67.3
Oregon	$3.7	$0.0	$1.2	$7.3
Pennsylvania	-$18.4	-$57.5	-$110.2	-$182.4
Rhode Island	$0.0	-$1.2	-$2.4	-$3.7
South Carolina	-$6.1	-$15.9	-$29.4	-$50.2
South Dakota	$0.0	-$2.4	-$6.1	-$9.8
Tennessee	-$19.6	-$61.2	-$134.7	-$231.4
Texas	-$42.8	-$145.7	-$226.5	-$352.6
Utah	-$3.7	-$19.6	-$57.5	-$61.2
Vermont	$0.0	-$1.2	-$2.4	-$4.9
Virginia	-$9.8	-$31.8	-$60.0	-$101.6
Washington	$4.9	$2.4	$7.3	$15.9
West Virginia	-$1.2	-$15.9	-$39.2	-$71.0
Wisconsin	-$2.4	-$15.9	-$41.6	-$86.9
Wyoming	-$1.2	-$6.1	-$12.2	-$20.8

Table E-23. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Utilities ($M)

Region	2020	2030	2040	2050
United States	$128.5	$871.6	$1,557.2	$270.6
Alabama	-$1.2	-$17.1	$149.4	$93.0
Arizona	-$91.8	$64.9	$154.3	$31.8
Arkansas	-$7.3	-$8.6	-$17.1	-$7.3
California	$255.9	$497.0	$1,590.3	$752.9
Colorado	-$23.3	-$14.7	-$2.4	-$4.9
Connecticut	$18.4	$26.9	$28.2	$26.9
Delaware	$2.4	$3.7	$4.9	$6.1
District of Columbia	$0.0	$0.0	$0.0	$0.0
Florida	-$17.1	$4.9	$33.1	$226.5
Georgia	$18.4	$14.7	$109.0	$120.0
Idaho	$1.2	$2.4	$3.7	$4.9
Illinois	$8.6	$9.8	-$106.5	-$254.6
Indiana	$2.4	-$49.0	-$153.0	-$241.2
Iowa	$2.4	-$4.9	-$40.4	-$73.5
Kansas	-$24.5	-$30.6	-$38.0	-$44.1
Kentucky	$0.0	-$23.3	-$91.8	-$230.2
Louisiana	$0.0	-$3.7	-$1.2	$77.1
Maine	$0.0	$1.2	$6.1	$9.8
Maryland	$0.0	-$1.2	$14.7	$25.7
Massachusetts	$23.3	$33.1	$38.0	$46.5
Michigan	$3.7	-$3.7	-$74.7	-$170.2
Minnesota	$7.3	$1.2	-$26.9	-$60.0
Mississippi	$1.2	$2.4	$8.6	$4.9
Missouri	$4.9	$7.3	-$41.6	-$69.8

Region	2020	2030	2040	2050
Montana	$2.4	$3.7	$6.1	$6.1
Nebraska	-$11.0	-$14.7	-$15.9	-$18.4
Nevada	-$20.8	-$18.4	-$9.8	-$26.9
New Hampshire	$0.0	$15.9	$18.4	$20.8
New Jersey	-$1.2	$15.9	$41.6	$51.4
New Mexico	-$29.4	-$49.0	-$51.4	-$57.5
New York	-$3.7	$64.9	$85.7	$73.5
North Carolina	$30.6	$90.6	$132.2	$122.4
North Dakota	-$7.3	-$9.8	-$8.6	-$15.9
Ohio	$3.7	-$82.0	-$161.6	-$252.2
Oklahoma	-$51.4	-$38.0	-$89.4	-$45.3
Oregon	$4.9	$8.6	$13.5	$19.6
Pennsylvania	-$2.4	$146.9	$181.2	$143.2
Rhode Island	$4.9	$2.4	$6.1	$6.1
South Carolina	$42.8	$61.2	$124.9	$148.1
South Dakota	$2.4	$2.4	$2.4	$2.4
Tennessee	-$28.2	-$97.9	-$146.9	-$182.4
Texas	-$15.9	$345.2	$111.4	$410.1
Utah	-$20.8	-$34.3	-$39.2	-$50.2
Vermont	$0.0	-$1.2	-$4.9	-$4.9
Virginia	$51.4	$60.0	$66.1	$63.7
Washington	$4.9	$8.6	$13.5	$18.4
West Virginia	$0.0	-$101.6	-$213.0	-$324.4
Wisconsin	$2.4	-$1.2	-$29.4	-$79.6
Wyoming	-$15.9	-$23.3	-$26.9	-$31.8

Table E-24. Change in Contribution to GDP and GSP by State and Industry Group (1% Case) for Wholesale Trade ($M)

Region	2020	2030	2040	2050	Region	2020	2030	2040	2050
United States	**-$706.4**	**-$1,891.4**	**-$3,036.1**	**-$4,425.6**	Montana	$0.0	-$1.2	-$2.4	-$3.7
Alabama	-$14.7	-$26.9	-$39.2	-$63.7	Nebraska	$0.0	-$4.9	-$11.0	-$18.4
Arizona	-$28.2	-$124.9	-$221.6	-$241.2	Nevada	-$7.3	-$34.3	-$88.1	-$58.8
Arkansas	-$6.1	-$12.2	-$18.4	-$29.4	New Hampshire	-$1.2	-$4.9	-$8.6	-$15.9
California	-$42.8	-$144.5	-$333.0	-$168.9	New Jersey	-$35.5	-$77.1	-$112.6	-$173.8
Colorado	-$6.1	-$69.8	-$68.6	-$100.4	New Mexico	-$7.3	-$39.2	-$39.2	-$51.4
Connecticut	-$6.1	-$15.9	-$24.5	-$39.2	New York	-$55.1	-$116.3	-$173.8	-$265.7
Delaware	-$2.4	-$6.1	-$8.6	-$13.5	North Carolina	-$41.6	-$72.2	-$102.8	-$161.6
District of Columbia	-$1.2	-$1.2	-$2.4	-$3.7	North Dakota	$0.0	-$2.4	-$4.9	-$8.6
Florida	-$113.9	-$181.2	-$247.3	-$348.9	Ohio	-$4.9	-$50.2	-$110.2	-$199.5
Georgia	-$82.0	-$129.8	-$178.7	-$269.3	Oklahoma	-$18.4	-$72.2	-$47.7	-$85.7
Idaho	$1.2	-$1.2	-$1.2	$0.0	Oregon	$11.0	$12.2	$25.7	$41.6
Illinois	$6.1	-$12.2	-$74.7	-$209.3	Pennsylvania	-$39.2	-$83.2	-$120.0	-$184.9
Indiana	-$1.2	-$18.4	-$53.9	-$110.2	Rhode Island	$0.0	-$1.2	-$2.4	-$4.9
Iowa	$2.4	-$3.7	-$14.7	-$31.8	South Carolina	-$14.7	-$24.5	-$34.3	-$52.6
Kansas	-$3.7	-$13.5	-$18.4	-$34.3	South Dakota	$0.0	-$1.2	-$3.7	-$6.1
Kentucky	-$8.6	-$20.8	-$62.4	-$122.4	Tennessee	-$26.9	-$57.5	-$104.1	-$164.0
Louisiana	-$7.3	-$17.1	-$23.3	-$40.4	Texas	-$104.1	-$264.4	-$318.3	-$484.8
Maine	$0.0	-$1.2	-$2.4	-$4.9	Utah	-$7.3	-$24.5	-$57.5	-$60.0
Maryland	-$13.5	-$30.6	-$45.3	-$75.9	Vermont	$0.0	-$1.2	-$3.7	-$4.9
Massachusetts	-$4.9	-$19.6	-$33.1	-$63.7	Virginia	-$24.5	-$49.0	-$68.6	-$110.2
Michigan	-$3.7	-$17.1	-$47.7	-$93.0	Washington	$14.7	$17.1	$38.0	$56.3
Minnesota	$0.0	-$13.5	-$40.4	-$88.1	West Virginia	-$2.4	-$30.6	-$61.2	-$106.5
Mississippi	-$2.4	-$7.3	-$11.0	-$19.6	Wisconsin	$0.0	-$4.9	-$23.3	-$53.9
Missouri	-$1.2	-$11.0	-$25.7	-$62.4	Wyoming	-$1.2	-$4.9	-$6.1	-$15.9

Appendix F. Loss Function for Small Exceedance Probabilities

Section 2.5 in the body of the report considers the problem of extrapolating the result between the 99% and 1% exceedance-probability interval and the 1% to 0% interval. The 1% to 0% interval is potentially problematic if the value of risk (probability multiplied by consequence) is either not convergent or has a value in excess of that explicitly simulated for the 99% to 1% exceedance-probability range. In this appendix, we develop and justify a functional form for extrapolation based on the underlying analogy of using the logic of a finite resource depletion to represent how the costs of climate change "deplete" the finite GDP.

Because we only address economic impacts, the maximum cost of climate change is limited to the near total loss of the entire GDP of the United States or the GSP (gross state product) of an individual state. In the extreme, with a probability of occurrence approaching 0%, there is the potential of losing most of the economy. We select an upper limit of a 90% loss of the U.S. GDP from the forecast by the macroeconomic referent (discussed in Appendix D). The limit to the maximum loss represents the GDP as if all areas of the United States, in the most extreme case of minimal precipitation, had a climate comparable to New Mexico. This maximum (finite) impact only occurs as the probability approaches zero in the impact distribution, and we assume that the climatic conditions only grow to dominance over the last 10 years of the analysis horizon, i.e., from 2040 to 2050. These assumptions lead to the fraction of loss having the following analytical form:

$$\textit{Fraction of GDP Loss}\ (t) = 0.0168 * (e^{(\frac{(t-2009)}{41}*4)} - 1), \quad 2010 \le t \le 2050. \tag{F-1}$$

The integral of Equation (F-1) and the reference GDP over time is the maximum cost (C_{max}) of the loss in the asymptotically most extreme circumstance, as in

$$C_{max} = \int_{2010}^{2050} \textit{Referent\_GDP} \times \textit{Fraction of GDP Lost} \times dt. \tag{F-2}$$

The probability of this fractional loss and its attendant risk depends on how fast the tail of the probability distribution falls to zero and how fast the costs rise with the risk variable, for example, temperature or precipitation (Yohe and Tol 2009).

In the absence of technological change, the concept of rising costs as a function of the reduced probability of finding additional (finite) resources emulates the consideration here of rising climate costs as extreme climatic conditions have diminishing probability.

Historically, the finding rate, R, for a finite resource was often approximated by an exponentially decreasing function, for example, the barrel of oil found per foot as a function of cumulative drilling feet, x (Ghosh and Prelas 2009; Hubbert 1969, 1982; Crovelli 1993):

$$R(x) \propto e^{-ux}. \tag{F-3}$$

The cost, C, of finding new resources then exponentially rises as the inverse of the finding rate:

$$C(x) \propto e^{+ux}. \tag{F-4}$$

Per Equation (F-3), the finding rate is a random variable whose values conform to an exponentially declining probability distribution. The change in the probability, p, of finding a new unit of oil per foot of drilling is just a scaling of the exponentially declining finding rate in terms of, for example, feet drilled:

$$p(x) \propto e^{-ux}. \tag{F-5}$$

Analogously, the temperature increase from climate change is comparable to the drilling activity (the tail of the distribution of temperature is well approximated by an exponential function); and the exponential cost function corresponds to the exponential damage-function approach recommended by Weitzman (2009). For this analogy to hold in a mathematical sense and establish a finite risk, the probability must fall no slower than exponentially. Because the tail of the gamma distribution of precipitation falls faster than the exponential function, the gamma distribution used to capture the uncertainty in precipitation due to climate change meets this criterion. In other words, the mathematical approach used in this appendix is compatible with the cumulative gamma distribution that describes how fast the precipitation goes to zero and, in tandem, how fast the losses are increasing.

The integral of Equation (F-3) represents the total use of a resource from 0% to 100% of its initial base, while the integration of Equation (F-5) captures the same concept. That is, the total finding of the resource with infinite drilling is the entire resource base, and by the time the probability of finding more of the resource goes to zero, the entire resource base has been exhausted. Equation (F-3) integrates to 100% of the resource base. Equation (F-5) integrates to 100% of the probability of finding the resource.

The resource exploited, E, is the integral of Equation (F-3) and a proportionality constant (K_1):

$$E(x) = \int_o^x K_1 \times e^{-ux} dx \tag{F-6}$$

or

$$E(x) = \frac{K_1}{\mu} \times (1 - e^{-ux}). \tag{F-7}$$

The integral from zero to infinity is the entire resource base, B:

$$E(\infty) = B = \frac{K_1}{\mu}. \tag{F-8}$$

Therefore,

$$E(x) = B \times (1 - e^{-ux}), \tag{F-9}$$

or

$$1 - \frac{B}{E} = e^{-ux}. \tag{F-10}$$

Define the term $1 - B/E$ as the fraction of the resource remaining, F. This term also represents the probability, p, of how much of the resource remains to be found at a given level of total drilling.

$$F = p = e^{-ux}. \tag{F-11}$$

Equation (F-3) and Equation (F-5) are equivalent, and we have used the two equations containing both the finding rate and the probability to make functions of the finding rate, x, into functions of the probability, p. Therefore, the integral of Equations (F-3) and (F-5) allows the transformation of Equation (F-4) from a function of feet-drilled into a function of probability. Equation (F-4) is transformed into a more formal equation with the use of a proportional constant, K_2. Then, substituting Equation (F-11) for the exponential term of Equation (F-4) gives

$$C = \frac{K_2}{p}. \tag{F-12}$$

In the more general case,

$$C(p) \propto \frac{1}{p}. \tag{F-13}$$

Although this exercise uses a concrete example of feet-drilled, the logic applies to any set of relationships where the probability of an occurrence declines exponentially, the consequence increases exponentially, and the integral of all occurrences has a specified finite value (such as the GDP in the actual concern of this study).

We can use C_{max} to limit the maximum value of Equation (F-12) when p goes to 0 to obtain

$$C(p) = 1/(\alpha p + \beta), \tag{F-14}$$

where α is the reciprocal of the known loss (e.g., GDP loss at the 1% exceedance probability) times its associated probability. The β term is the reciprocal of C_{max}. The value of α is much larger than that of β. In the absence of β, the loss would go to infinity as the probability goes to 0.0. The β term limits the loss to the maximum it specifies. We can formally derive the functional form of the denominator of Equation (F-14) but here simply state that it has the required mathematical characteristics for our purposes. We use Equation (F-14) to extrapolate the cost, C, or loss over the range of the 1% to 0% exceedance probabilities.

As noted in Section 2.5, the maximum loss is assumed to be 90% of the GDP. From Section 4 of the main text, the simulated 1% exceedance-probability loss is in the range of tenths to a single-digit percentage of the GDP for the nation and the individual states. In using the 1% exceedance-probability cost for determining α, empirically and definitionally α is much larger than β.

Equation (F-14) is the analytical function used for extrapolating costs within the 1% to 0% exceedance-probability interval.

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Appendix G. The Discount Rate with Proportional Costs

As noted in Section 1.2, economic studies use a discount rate to assign a value in the present to costs that will occur in the future. Also as noted in Section 1.2, the determination of the discount rate is often represented by the equation

$$r = p + \theta * g. \tag{G-1}$$

Here, r is the social discount rate, p is the pure rate of time preference (PRTP), θ is the income elasticity of the marginal utility of consumption, and g is the growth rate in per capita consumption. Cline (1992) provides a relatively complete derivation of Equation (G-1), but Cline's derivation is based on absolute (or additive) costs. With precipitation as the primary uncertainty, the damage costs are proportional to the size of the economy, and the justification for the θ in Equation (G-1) may be absent. This appendix provides one justification for disregarding θ under such situations.

If the costs associated with climate change have a positive or negative effect on the economy, the emphasis on future, richer generations having a better ability to cope with climate-related costs may have some merit. (Note that this approach disregards concerns that the ecological footprint of humankind indicates increasing consumption may be unsustainable even into the midterm future [Wackernagel et al. 2002; Lenzen and Murray 2003]). If the costs are proportional to the existing economy, Cline's (1992) derivation may not apply as the equations below indicate.

If the utility, U, of consumption, C, is

$$U \propto K \times C^{\alpha}, \tag{G-2}$$

where $0.0 < \alpha < 1.0$, and K is a constant, and if consumption is a share, S, of the economy, and if the climate impacts are proportional, F, to the size of the economy, then the fractional change in utility is

$$\Delta U / U = K(C^{\alpha} - (1 - S \times F) \times C^{\alpha}) / (K \times C^{\alpha}) \tag{G-3}$$

or

$$\Delta U / U = S \times F. \tag{G-4}$$

Therefore, the change in utility is independent of the level of consumption, contrary to the implicit assumption in Equation G-1.

An allometric function (econometrically estimated as a log-linear function), such as that represented by Equation G-2, commonly describes economic data. Monetary value is a relative concept. A dollar in 1920 had much more buying power than a dollar today, but it could not buy the conveniences we have today. Proportional measures of value maintain their meaning whether measured in yen or dollars, in the year 1850 or 2050. Using the conventional assumptions of a homogenous population and the allometric representation for the utility of consumption (Equation [G-2]), Equation [G-4]) indicates that a 20% loss in consumption for Warren Buffet is the same proportional loss in utility as a 20% loss to a minimum wage worker. Such a proportional loss is independent of the level of consumption, and thus the utility is not a function of income levels. Although it is possible to argue that increased temperature has positive or negative impacts, this study shows that the impact of reduced precipitation is clearly proportional. Therefore, the second term in the discount equation becomes questionable at best and possibly not applicable. As such, only the PRTP term may have meaning, and as noted above, some economists rationalize its value as being close to zero (Quiggin 2008).

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